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Physiography of the St. Louis Area

BY

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CONTENTS.

Contents—Continued.

Contents—Concluded.

LIST OF ILLUSTRATIONS.

PLATES.

FIGURES.

LETTER OF TRANSMITTAL.

STATE GEOLOGICAL SURVEY,
UNIVERSITY OF ILLINOIS,
URBANA, ILL., May 18th, 1909.

Governor C. S. Deneen, Chairman, and Members of the Geological Commission:

GENTLEMEN—I submit herewith a report on the Physiography of the Saint Louis Area, with a recommendation that it be published as Bulletin 12 of the survey. This forms the third of the series of "Educational Bulletins" planned by Doctor Bain and prepared under the general direction of Professor R. D. Salisbury of the University of Chicago, Consulting Geologist of the Survey. The author, Doctor N. M. Fenneman, made the field studies on which this report is based in the summer of 1906, at which time he was Professor of Physiographic Geology at the University of Wisconsin. He is now Professor of Geology at the University of Cincinnati. The field work was done under the joint auspices of the U. S. Geological Survey and the Illinois Geological Survey, and Doctor Fenneman was assisted by Mr. J. C. Jones.

This area, because of its exceptional wealth of illustrations of physiographic forms, was one of the first chosen to be reported on in this series. It includes almost equal parts of Illinois and Missouri and the heart of one of our greatest industrial centers. Doctor Fenneman's clear and systematic description of the work of the principal physiographic agents has been splendidly illustrated from the uplands and the exceptionally interesting floodplain, known as the "Great American Bottoms." Doubtless the report will be of particular interest to people living in the vicinity and especially to teachers and students but also to those all over the State, interested in physiographic studies.

The survey is under great obligations to Professor Salisbury and to the author of this report, and to others who assisted in its preparation. Acknowledgment should especially be made to the Mississippi River Commission and to the U. S. Engineers in charge of Mississippi river studies for the use of valuable maps and other data, and also to the U. S. Geological Survey for the use of Plate 17 and the topographic base limestone in the making of caves and sinkholes is here shown in unusual perfection. Peneplains, uplifted and dissected, are nowhere better exemplified. The loess has a peculiar interest, first because of its abundance and typical character and second because of its gradation within short distances into other types which are widely known and very important elsewhere. These are the "white clay" of southern Illinois, Indiana and Ohio, and the "brown loam" so characteristic of Mississippi and other southern states.

The location and wider geographic relations of this great center of population are themselves of special interest. All physiographic features, therefore, which have played a part in controlling the life and history of a great city, have a geographic significance.

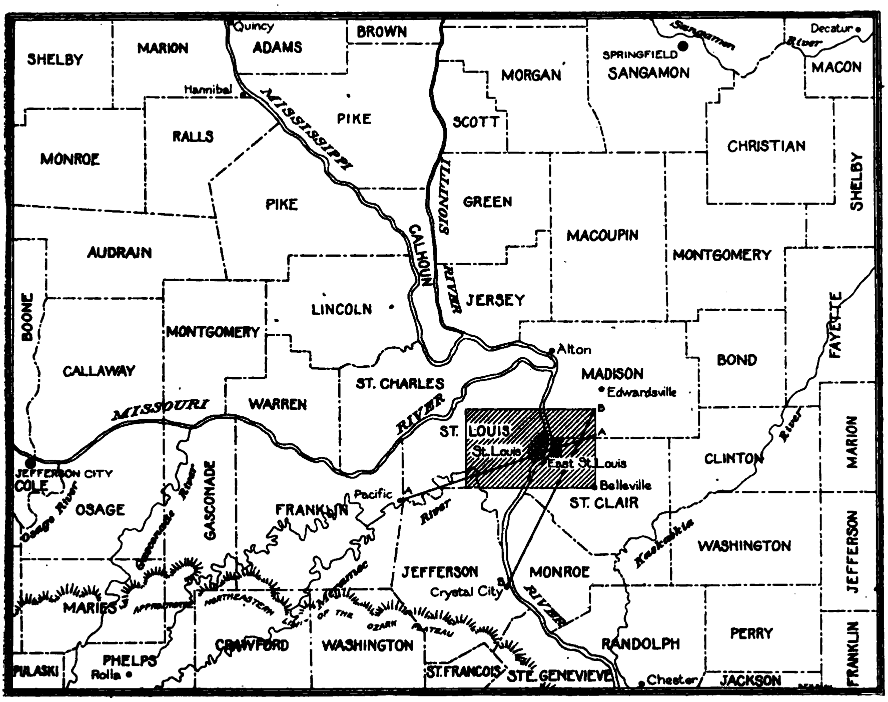

FIG. 1. Index Map showing location of the area.

ACKNOWLEDGMENTS.

The field work on which this report is based was done in the summer of 1906 under the joint auspices of the United States Geological Survey and the Illinois State Geological Survey. A separate report of different character has already been submitted to the former. The writer of this report is indebted to the various officials of both these organizations for counsel and assistance and especially to Professor R. D. Salisbury, in charge of the preparation of educational bulletins. The geological map is in the main, the work of Mr. J. C. Jones, a member of the party employed by the Illinois Geological Survey. Valuable maps and data

were received from the Mississippi River Commission and the United States Engineers in charge of the Mississippi river above the mouth of the Ohio.

The interest taken in the work by many citizens of St. Louis gave very material assistance in collecting important data not directly obtainable in the field. Mr. Arthur Thacher is especially to be thanked for assistance of this character. Generous help was also received from Mr. H. A. Wheeler whose former work on the Missouri Geological Survey gave him special familiarity with the region; from Mr. George More, whose experience in bridge building put him in possession of valuable data regarding the formations beneath the channel of the Mississippi and Missouri rivers; from Mr. William B. Potter, Manager of the St. Louis Sampling and Testing Works, who has made many analyses of water from this vicinity; from Mr. Charles W. Francis, Assistant Health Commissioner, who furnished data concerning the wells of St. Louis; and from Mr. Pierre Chouteau who furnished data concerning the early history of St. Louis. The information and assistance received from various well drillers and managers or other officers of clay mines and factories, quarries, etc., was so varied and abundant as to preclude the enumeration of individual names.

The writer was at various times accompanied in the field by Dr. W. J. McGee, whose many suggestions were of much value, not only directly, but indirectly by adding to the pleasure and interest of the work. A similar acknowledgment is made to Mr. Gerard Fowke, who is familiar with the field and who accompanied the writer several days.

UNDERLYING ROCKS.

In describing and explaining surface features and geographic facts, the nature and subdivisions of the underlying rocks must be so frequently referred to that a comprehensive picture of their character and relations must be kept in mind. They have a great bearing on the industrial life of the community, for from them come building stones, coal, clays of various kinds, glass sand, and water. The changing geography of this region since the first land appeared can be known only by the records contained in these rocks. Their chief interest in the present study is, however, in the control which they have exercised over the history and character of the present topography.

General View.

In a most general way the best known rocks beneath this area, that is the first 1,200 or 1,500 feet of strata, consist mainly of limestone and are therefore capable of being dissolved by ground waters. Over about one-half of the area, this limestone is overlain by shales which resist solution, but which waste away by being comminuted and carried as mud in the streams. Within the limestone itself are several layers of similar shale which not only do not dissolve but which prevent the ground water from ascending and descending through them. There is almost no sandstone within the first 1,200 or 1,500 feet beneath the surface, but below this level is a bed more than 100 feet thick, which is loose, porous and filled with water. The strata beneath this are of little interest here.

A second element of the general view is a slight tilting of the strata toward the northeast so that the sandstone, which is some 1,500 feet below the surface at St. Louis, is more than 2,000 feet deep at Monks Mound in Illinois only 7 miles from the Eads bridge.[1] The same sandstone comes to the surface at Pacific, about 33 miles west of the bridge (Pl. 1, A.), and at Crystal City, which is about 30 miles to the south (Pl. 1, B.)

On account of this tilt or dip an observer west or south of St. Louis finds the same strata exposed at the surface which are penetrated in deep wells in the city. Those found at the bottom of city wells several thou-

[1]For the sake of location it is convenient to know that the Eads Bridge crosses the Mississippi between the centers of St. Louis and East St. Louis.

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sand feet deep, come to the surface 30 or more miles distant. A number of such deep wells have been drilled and samples kept of the rock at frequent intervals. Such records are very valuable when studied in connection with the outcrops.

The general dip to the northeast is much steeper at some places than at others. In at least one place the dip is reversed because of a minor transverse fold which extends from the east end of Forest Park, St. Louis, in a direction east of south, past Arsenal Island and probably far into Illinois.[1] Both the general dip and the transverse fold are shown in Plate 1 A.

FORMATIONS DESCRIBED.

In the following somewhat fuller description of the several formations it is convenient to begin with the best known, that is, those at the surface.

ALLUVIUM.

While not occupying the highest place topographically, the alluvium of existing floodplains stands at the top of the geological column. It is the latest deposit; is still, in fact, accumulating, and no other geological formation overlies it. It follows that it may contain material derived from any or all of the older formations. The materials of the alluvium in this area are not, of course, derived in the main from the older formations close at hand, but from the rocks crossed by the upper courses of the rivers. Most of these sources are, however, represented, at least in a general way, by the older formations within the area.

Smaller Streams in Illinois.—The materials of the alluvium are sand, gravel and mud. The constitutent stones of the gravel and constitutent particles of the sand and mud differ along different streams, depending on the nature of the rocks over which the upper courses of the streams flow. The small streams flowing west into the Mississippi from Madison and St. Clair counties, Illinois, have flood-plains whose material is derived chiefly from the loess which they have gathered from the uplands, worked over, and laid down in a condition but little changed. The general absence of coarser material is not because of the inability of the streams to transport larger particles, but because there is little or no supply of such particles. The smaller streams west of the Mississippi differ little in this respect from those on the east side.

Meramec River.—The Meramec, coming down from the Ozark Highland, is bordered by alluvium consisting largely of chert, for of all the materials over which it flows, chert is the substance which best withstands wear and resists solution. The alluvium of this stream is, moreover, largely gravel, for the double reason that the Meramec finds coarse material along its route and flows swiftly enough to transport it.

Mississippi River.—The Mississippi and its tributaries like the Illinois, coming from the north, bring many fragments and particles of

[1]See Weller S., Geologic Structure of the State, Bulletin Ill. Geol. Survey, No. 2, 1906, p. 22.

crystalline rocks from the glacial drift, and the material of their flood-plains is characterized by these. This alluvium is chiefly sand, not because the Mississippi cannot transport gravel, but partly because finer particles predominate in the material delivered to it, and partly because the larger particles are broken up by attrition.

In the Mississippi flood-plain the upper 10 or 12 feet of sediment are chiefly mud and clay. Beneath this, to a depth of 50 to 150 feet, the great body of alluvium is largely sand. There are, however, subordinate thin beds or lenses of clay and gravel. Beneath the sand and lying on the solid rock in which the trough is cut, is gravel, sometimes so coarse as to be more properly called a bed of bowlders. The reasons for this distribution can best be given after the behavior of rivers has been discussed.

With the alluvium should be mentioned another class of deposits likewise accumulating at the present time. These are the sediments of the lakes on the flood-plain. The muds and clays of the lakes are not sharply distinguished from the alluvial mud. The designation "river bottom" deposits is frequently used for both kinds indiscriminately, and it includes also the black muck, which is organic matter mixed with mud in any proportion, or which may be so free from mud as to form deposits of peat.

LOESS.

Geological Position.—Next older than the alluvium is the loess which covers the uplands to a depth varying from a few feet to 50 feet, being thickest near the bluffs, and thinning to an average of 10 or 15 feet within a few miles. In the main, the loess and the alluvium occupy different areas, the former being on high ground and the latter on low. Despite this circumstance, however, the loess must be regarded as lower, that is older geologically, for the material of the modern alluvium is derived in part from the loess. The effects of the reverse process if present at all, are relatively insignificant. If then the two be found on the same spot, the alluvium must be on top. An apparent exception to this rule is found in places at the edge of the flood-plain (Fig. 2), but the loess which is here spread out over the edges of the river alluvium has been washed down later from the face of the bluff and is itself a kind of alluvium, accumulated at the base of the bluff.

Physical Properties.—The loess is an unconsolidated substance somewhat resembling yellow clay, but of a mealy nature so that when not quite dry it is readily pulverized in the hand, passing into a fine flour instead of forming crumbs, balls or hard lumps as clay does. A peculiar property of loess is its tendency, despite its mealy or loamy nature, to crack along vertical planes. An exposure therefore tends to present a vertical face, often showing prismatic columns outlined by the jointing cracks, (Pl. 2). Where surface waters pass over a loess cliff, its verticality is soon lost, but, barring the effect of such wash, a cliff made by excavation may remain vertical for many years. Loess is the material commonly seen on the upland wherever the surface soil is cut through, and most abundantly near the bluffs, as in the city of St. Louis. It is

A—Loess 2 miles north of Collinsville, Illinois.

B—Loess in railroad cut near Kinloch, Missouri. The original sloping face is becoming vertical by the slumping of masses broken off along vertical cleavage planes.

much used in making red brick and is generally, but somewhat incorrectly called "clay." It would be more accurate to say that it *contains* enough clay to make it plastic when wet.

Constitution.—The loess at Kansas City has been carefully studied under the microscope by Professor Salisbury[1] and found to consist of small angular particles of the same minerals which make up the rocks of the glacial drift. Those examined and measured ranged in size up to a maximum of about one-tenth of a millimeter or one-two hundred fiftieth of an inch. Not more than one per cent of all the 87,135 particles of Kansas City loess which were measured had a diameter exceeding one-two hundredth of a millimeter, and 96 per cent of all had diameters less than one-four hundredth of a millimeter or one-ten thousandth of an inch. One of the important physical characteristics of the loess, namely, its firm packing, a property which sometimes makes it usable as moulders' sand, seems to depend on the presence of angular grains of all sizes below the maximum.

Embedded in the loess at some places are many calcareous concretions, ranging in size from that of a pea up to a maximum of several inches in diameter. These may be nearly spherical nodules or irregular rough and branching growths. Gastropod shells belonging to land species now living are abundant at some places, especially along the bluffs in Illinois.

Variation in Character.—The description of the loess as given above applies to much the larger part of that formation within the area embraced in this report. Especially is this true of the loess on the bluffs which is often 40 or even 50 feet thick. Where the loess has this character, lines of stratification are generally though not always absent. At places stratification is clearly shown, sometimes in long continuous horizontal lines, sometimes in wavy and inclined lines. In the former case the beds may show alternations of coarser and finer material, or of true loess and a coarser silt.

The upper 3 or 4 feet of the loess is generally more like a stiff clay because many of the minute rock particles have been converted into clay by weathering. The lower limit of this clayey portion is fairly distinct, this limit probably being determined by the percolation of rain waters which carry the fine products of decomposition downward among the original particles. This layer is called the "strong clay" by brick makers. It constitutes the subsoil and on its upper side shades gradually into the surface soil.

At the bottom of the loess there is generally a thickness of 2 or 3 feet within which small gravel stones abound. These stones are of the usual kinds found in the glacial drift. The matrix in which they are embedded resembles the loess, and it is customary to class this gravelly horizon as the basal portion of the loess. As the base is approached, this matrix often gets more clayey and may grade into a stiff red or brown clay which is apparently a product of weathering from the underlying shales or limestones. Most of these features are clearly shown in any railroad cut which goes down to bed rock and on the walls of the many quarries in St. Louis.

[1]Chamberlin, T. C., and Salisbury, R. D., The Driftless Area of the Upper Mississippi, 6th Annual Rept. U. S. Geol. Survey, 1885, p. 281.

A type of loess which is far less abundant than that described above has a gray color and less coherence. It is more like silt, presumably being composed of grains better assorted as to size. This is common at low levels, not much above that of the larger rivers, as at Carondelet, Missouri. Well defined stratification is more common in this than in the yellow loess. It may, however, be unstratified and is sometimes found high in the bluffs, as for example, east of Centerville, Illinois.

At a distance of a few miles back from the bluffs the loess becomes more clayey, and its average thickness decreases to 10 or 15 feet. East of the Mississippi its color becomes lighter. Over the uplands of southern Illinois and Indiana it is generally known as the "white clay."[1]

An extension of the same sheet over Mississippi and adjacent states is known as the "brown loam." It is decidedly darker and more clayey than the loess of the river bluffs. The transition is so gradual that it is impossible to draw the limits of the several phases. The change begins to become apparent within a few miles of St. Louis.

GLACIAL DRIFT.

Over most of this area in Illinois and a part of it in Missouri, the loess is underlain by a layer of intermingled stones, sand and clay. This material is frequently passed in drilling or digging wells, but, owing to the presence of gravel in the base of the loess, the distinction between that formation and the coarser material below is liable to escape notice. This lower material is bowlder clay or glacial drift deposited directly by the ice. It occurs in two phases differing in appearance and originating in two distinct ice invasions or glacial epochs, the Kansan and the Illinoian.

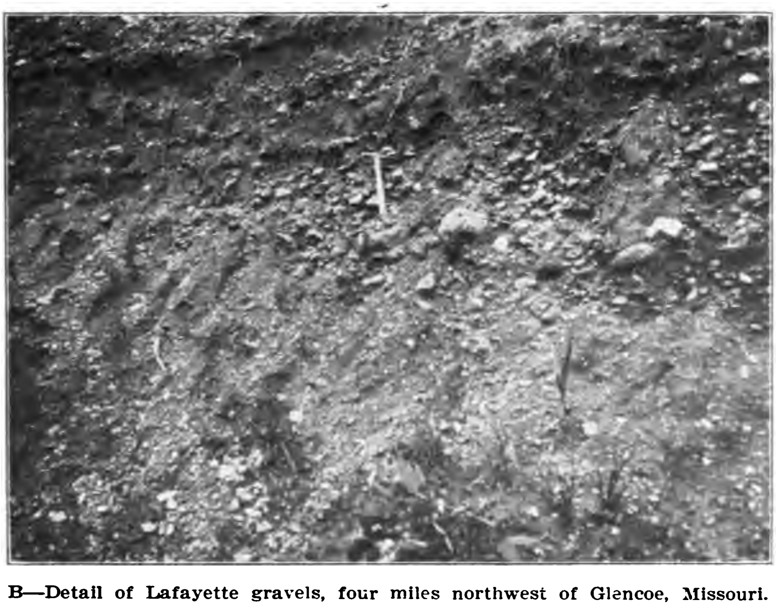
Illinoian.—Drift of the Illinoian epoch is occasionally exposed on the steep slope of the Mississippi bluff in Illinois and in ravines indenting the bluff. Railroad cuts several miles east of Caseyville make numerous exposures of this bowlder clay, though in none of them are large bowlders found. A small tributary of Canteen Creek in Section 20, Caseyville Township, Illinois, has bowlders of crystalline rock several feet in diameter in its bed. About 2 miles south of Edgemont, excavation for a railroad following the face of the bluff has made exposures similar to those east of Caseyville.

More satisfactory exposures are found both north and south of the East St. Louis quadrangle. At Edwardsville, from 40 to 60 feet of drift are known both by natural exposure and from well records. Taking Madison county as a whole, Leverett estimates from the data of wells that the average thickness exceeds 40 feet.

In the bluff on the Missouri side, such a deposit may be seen about 2 miles north of the St. Louis Water Works pumping station at the Chain-of-rocks, which lies just north of the area mapped for this re-

[1]Leverett, Frank.—The Illinois Glacial Lobe, Mon. 38, U. S. Geol. Survey, p. 158.

A—Lafayette gravels on Carboniferous Shales; four miles northwest of Glencoe, Missouri.



B—Detail of Lafayette gravels, four miles northwest of Glencoe, Missouri.

port. At various places in St. Louis excavation has revealed beneath the loess a deposit containing crystalline bowlders, which is believed to represent till of the Illinoian epoch.[1]

Kansan.—At a few points on the peninsula between the Mississippi and Missouri rivers near their junction, glacial drift is found which differs in several ways from that described above, and classified as Illinoian. It contains no large bowlders, and all its crystalline pebbles are in an advanced state of decomposition. This is especially true of the dark colored ones whose iron-bearing minerals are thoroughly oxidized and whose feldspars are known only by the kaolin which remains from their decomposition. These deposits are probably of the Kansan glacial epoch. One such deposit is found beneath the supposed Illinois drift 2 miles north of the St. Louis water works. It is separated from that above by several feet of stratified clay which may have been laid down during the interval between the Kansan and Illinoian epochs. A large amount of similar, but less weathered material is found in a steep bluff of Watkins Creek not far from the water works.

LAFAYETTE GRAVEL.

In the western part of the St. Louis quadrangle and still farther west there are, underlying the loess, isolated patches of gravel very different from that at the base of the loess and very different from the glacial drift. This consists of well rounded pebbles of very resistant rocks such as quartzite, vein quartz, chert and jasper. These pebbles are generally small, averaging less than an inch in diameter, but many are larger and an occasional one may weigh many pounds. Between the stones is a matrix of clayey sand having the color of iron rust, or being of a brighter red. Sometimes this matrix appears in thin beds by itself, alternating with the gravel (Pl. 3).

This gravel is known as the *Lafayette formation.* Its character is well shown in a pit near the St. Louis and San Francisco railroad, west of the station at Webster Groves. It is generally found only on the highest hills, as at Stratmann and the elevated ground 2 miles north. At both of these places it is completely covered by loess and is known only from excavations and from the mixture of its pebbles with the detritus carried by the small streams which radiate from these hills. An excellent exposure of the Lafayette occurs 2 miles northwest of Ballwin (20 miles west of St. Louis) and others on the high ground about 3 miles north of Glencoe, a station on the Missouri Pacific Rairoad, 25 miles west of St. Louis.

1Mr. H. A. Wheeler (Trans. St. Louis Academy of Science, Vol. VII, pt. 3, 1905, p ...) describes the occurrence of a typical bowlder clay encountered in digging a tunnel under .... and Taylor avenues. Various igneous rocks which are common in the northern drift are enumerated.

Prof. J. E. Todd (Mo. Geol. Surv., Vol. X, p. 162) describes a cut which disclosed beneath the loess, 8 feet of "bowldery clay or till" in which a few igneous bowlders were found, though most were fragments of limestone.

Prof. G. Frederick Wright noted near Forest Park, striated pebbles ranging in size up to 3 inches and some thin limestone chips striated on one side only, perhaps broken from bed rock, and if so, evidently not transported far.

Dr. A. W. Worthen (Ill. Geol. Surv. Rept., Vol. I, 1866, p. 314) mentions "15 feet of common chocolate colored brown drift clay" exposed in a mound in the northern part of the city, though his language elsewhere does not indicate a sharp distinction among the various classes of surficial deposit know as "drift."

CARBONIFEROUS.

Coal Measures or Pennsylvanian.

If all the above named unconsolidated deposits were removed about one-half the area mapped would be found covered with beds of solid rock collectively known as the *Coal Measures* or upper part of the carboniferous system. Coal constitutes less than 2 per cent of their entire mass. Shale and clay are the most abundant constituents, after which follow sandstone and limestone. All these beds together have, on the Illinois side, a thickness of more than 400 feet, the principal coal bed, called the Belleville seam, being about 120 feet from the top. On the Missouri side the total thickness is generally less than 100 feet. There are two thin and local coal seams, not now worked.

A very important part of the Coal Measures is the bed of fire clay near the base of the formation west of the Mississippi. It is unconsolidated, and ranges in thickness from 2 to 12 feet. It is extensively mined in and near St. Louis and affords the material for a great industry.

Mississippian.

Chester.—Below the Coal Measures on the Illinois side is a porous sandstone belonging to the Chester formation. It has a maximum thickness of at least 75 feet. This is the topmost member of the Lower Carboniferous or Mississippian system in this area. It is of interest as being an important water bearer.

St. Louis Limestone.—Beneath the Coal Measures and Chester, and, where these are absent, immediately beneath the loess, is a great limestone formation, called the St. Louis because it is so well known in that locality. Its total thickness is more than 300 feet, but where not covered by the Coal Measures some of its upper part has been eroded away. It is the rock which makes the Mississippi bluffs south of St. Louis, and the remarkably fine bluff south of Prairie du Pont Creek in Illinois. It is also well known in the many deep quarries which form great vertical-walled pits sometimes nearly 100 feet deep, in the heart of St. Louis. Many churches and other large buildings in that city are built of this stone.

One of the characteristics which aids in distinguishing the St. Louis from other limestones is the prevalence of beds having an exceedingly dense and fine-grained texture. Where limestone of this nature is free from silica grains, and can be taken out in large slabs, it is valuable for lithographing. The St. Louis has been tried occasionally for that purpose, but the success has not been such as to bring it into general use.

Another feature of the formation is its chert or impure flint. This generally has the form of spherical or ellipsoidal nodules a few inches in diameter, but sometimes of continuous bands. Fortunately for building purposes, some of the beds are nearly or quite free from chert.

Spergen Limestone.—Beneath the St. Louis is another limestone 60 or more feet thick and much like that above, but coarser in grain, thicker bedded, and free from chert. This is the Spergen limestone, made famous as a building stone over the entire Mississippi Valley, by the great quarries near Bedford, Ind. Some of its beds here closely resemble those at Bedford, but it is little quarried in this area. Its relation to the Spergen limestone in Indiana is not determined by this resemblance, but by the fossils which are abundant at both places and almost identical in species. On the Illinois side it does not appear at the surface in this area except at one point in the bluff 3 miles south of Stolle. In St. Louis it is revealed at a single place, the workhouse quarry. Its position at the surface at both places is due to an upward fold of the rocks (see p 5). The Spergen outcrops, often in prominent cliffs, in the bluffs of the Meramec river.

Warsaw Shales.—Beneath the Spergen limestone are 75 feet of limestone and shale, called the Warsaw formation. The presence of this shale is important both in its effect on the topography and on the movement of ground waters. The formation can rarely be studied at the outcrop, because the shale weathers readily and wastes away and is therefore generally covered with loose surface materials. It may be examined in some of the ravines indenting the bluffs of the Meramec.

Osage Limestone.—A still lower formation about 200 feet thick and outcropping only in the valley of the Meramec, is the Osage limestone. It contains an abundance of chert, sometimes in the form of separate nodules, but oftener in bands, so that an exposure has the appearance of alternating beds of limestone and chert. Much of the limestone is made of fragments of fossils, crystallized. These with intervening crystals of calcite, make a coarse-grained rock. Because of the prevalence of fragments of crinoid stems, the name Encrinital limestone was once in general use to designate the Osage.

Kinderhook Limestone and Shale.—Beneath the Osage and at the bottom of the Lower Carboniferous or Mississippian system is a rather complex formation of limestone and shale with an occasional patch of sandstone near the base. These beds are about 100 feet thick and are known as the Kinderhook formation or series. It does not outcrop within the area mapped, but is of much interest because of its easy recognition when drilled through in deep wells. This is because of the red color of its shale member. This shale, which is 630 feet beneath the surface of the Mississippi river at the Eads bridge, comes to the surface in a good exposure at Fern Glenn on the Missouri Pacific Railroad, 20 miles west of St. Louis and 2 miles west of the area mapped. It is therefore known as the *Fern Glenn shale.* Its recognition in many deep borings has made its depth known at various places and has thus been one of the principal aids in determining the dips of the strata.

THE ORDOVICIAN SYSTEM.

Beneath the Carboniferous are many hundred feet of limestones and shales which have little interest here from a physiographic point of view. Of these the Trenton limestone is well known because it is the great oil and gas bearing rock of western Ohio and Indiana. The St. Peter's sandstone below it is of interest because of its recognition in deep wells, thus affording, like the Fern Glenn shale, a definite geological horizon which can be traced from well to well and identified. Data thus obtained give the basis for Plate 1, A. and B. The St. Peter's has a further interest because of the glass sand from it, which affords the material of a great industry. The saline water of the Belcher well, St. Louis, comes from this formation, which at that point (near the Eads bridge) is 1,500 feet beneath the surface.

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TOPOGRAPHY.

The topographic features of this region can best be described under three main heads, broad valleys, narrow valleys, and uplands. These are named and will be discussed in the order of their prominence to the casual observer. The upland is however the major feature and the standard of reference for the others.

BROAD VALLEYS.

The river valleys fall naturally into two orders of size, the Mississippi, Missouri and Meramec valleys constituting one class, and all other valleys the other. The division is not a purely arbitrary one based on the capacity of the streams, for the streams of each class differ more among themselves in size than the smallest stream of the first class differs from the largest of the second. The distinction is based on the features of the valleys. The streams of those here classed as *broad,* flow over deep beds of alluvium, constituting prominent flood-plains limited by generally abrupt bluffs.

THE MISSISSIPPI TROUGH.[1]

The most prominent of all topographic features of this region is the great trough of the Mississippi. It crosses the area from north to south, its width ranging from 3 to 10 miles, and its depth from 150 to 200 feet.

The Flood Plain.—Viewed from any high point on its border, the flood-plain which is the floor of the Mississippi trough appears quite flat, and almost everywhere terminates abruptly against steep bluffs.

In a general way this plain has a southward slope about equal to that of the river's fall. This is about 3⅔ inches per mile. Zero of the river gauge at the Eads bridge, St. Louis, is taken at 380.23 feet above sea level; the corresponding water elevation at the chain-of-rocks 10.2 miles to the north is 384.31 feet and at Jefferson Barracks 10.7 miles to the

1The term "valley" is frequently used almost synonymously with river basin—e. g., the "Mississippi valley"—and hence includes far more than is here intended. There is no technical term denoting that part of a river's valley included between its bluffs and considered with reference to its vertical dimension as well as the other two. In the absence of a universally accepted term, the word "trough" is here employed in that sense. Even this is not definite, for it is sometimes convenient to consider the flood plain as the bottom or floor of this trough, while at other times the word seems to be needed to designate the depression which would exist in the surface of the bed rock if the alluvium were removed. In this latter sense the term "rock trough" is generally appropriate.

south 377.94 feet. The bottom of the channel is a number of feet lower, but the amount cannot be definitely stated because of constant change in position, form and depth. The actual southward slope of the flood-plain in this vicinity is approximately twice as great as the river's fall, its height above the river between Granite City and Peters Station, being a little more than 20 feet or about 5 feet greater than the corresponding height between East Corondelet and Falling Spring.

There is no general slope toward or from the river, but from Edgemont northward a strip a mile or more in width at the foot of the bluff has a decided westerly slope, due chiefly to the waste from the bluffs.

The flatness of the plain is further interrupted by low linear swells and intervening shallow swales, the relief thus caused being from 5 to 10 feet (Pl. 4). The breadth of these undulations varies from perhaps one-tenth of a mile to half a mile. Their direction is roughly parallel to the river, or to some former channel. It is therefore generally more nearly north-south than east-west.

Both the ridges and the intervening slashes are liable to overflow, but the former are generally dry enough to farm. The latter are frequently marshy and in a few cases contain permanent lakes (Pl. 5). Two of the bodies of water, Horseshoe Lake, northeast of East St. Louis, and Pittsburg Lake to the southeast, have areas of approximately 4 square miles each at ordinary stages of the water. The sizes of the smaller lakes vary greatly from time to time. All these lakes are of the ox-bow type. Being unfilled remnants of former river channels, they are shallow and are rapidly filling with vegetal remains and mud from storm waters. Even now their bottoms are well above the water of the river. The surface of Horseshoe Lake is 16 feet higher than the low water level of the river directly opposite, while that of Pittsburg Lake which is nearer to the bluff is 24 feet above the corresponding datum.

South of Horseshoe Lake and some 7 miles northeast of the Eads bridge is a group of mounds occupying an area of 3 or 4 square miles. The largest of these is Monks Mound (Pl. 6 A) which is about 85 feet high and has an approximately rectangular base whose longer side is about 1,000 feet. The top is terraced in a form which is quite as artificial as the rectangular base. Some other of the larger mounds are conical but so symmetrical and steep-sided that the artificial character of their form is evident. Some of the smaller mounds are roughly circular or oval, being but a few rods in diameter and a few feet high and having gentle slopes (Pl. 6 B). Their forms are such as to suggest isolated and unconsumed remnants of bluffs or terraces.

The Bluffs.—The bluffs are characteristically though not universally steep, rising to their full height of several hundred feet within a horizontal distance of a few hundred yards. The line separating flood-plain and bluff is almost everywhere so sharp that the limit may be determined within a few rods. The gradation between the steep slopes of the latter and the nearly horizontal surface of the former is effected along a narrow strip where the material washed down from the bluff rests against its base and extends out with decreasing slope a short distance over the alluvium laid down by the river. This slope is generally very notice-

A—South end of Pittsburg Lake, looking west.

B—Nearer view of Pittsburg Lake.

A—Monk's Mound viewed from the southeast. This mound is apparently of natural origin up to a level somewhat below that of the terrace seen on the left. The remaining height and the shape of the whole are probably artificial.

B—Group of Mounds one-half mile south of Monk's Mound. The low grassy knoll at the left is believed to be entirely natural. It suggests the original forms of the larger mounds which have been artificially shaped.

Bluffs of Mississippi near Centerville, Illinois. The flood plain on the left is 170 feet below the upland.

able for a distance of a few hundred feet or even a few hundred yards. Exceptionally, as north of Edgemont it extends a mile or more from the bluffs (Fig 2).

The steepest bluffs are, as might be expected, of the hardest rock. This is best illustrated in the nearly vertical wall of limestone south of Prairie du Pont Creek on the Illinois side. Its maximum height is about 250 feet. Similar bluffs are seen on the Missouri side opposite Arsenal Island, and south of Jefferson Barracks. It is noteworthy also that these steepest bluffs occur where the trough is narrowest, and consequently where its limiting walls are most frequently and most vigorously undercut by the stream, as it swings from one side of the trough to the other.

North of Prairie du Pont Creek on the Illinois side, and north of the city of St. Louis on the Missouri side, the bluffs are cut in the softer beds of the Coal Measures but are at most places so thickly covered with loess that the rock does not appear. Here the slopes are less steep, though still abrupt (Pl. 7). They are also notched by ravines at more or less regular intervals. Being too steep for profitable farming, these bluffs and ravines are generally wooded and often appear in striking contrast to the fertile farm lands above and below.

THE MISSOURI TROUGH.

The small portion of the Missouri trough occupying the northwest corner of the area mapped is very similar to that of the Mississippi. It is about 3 miles wide and bounded by abrupt bluffs of limestone. The topography of its alluvial floor is similar to that of the Mississippi flood-plains.

Creve Coeur Lake has the same origin as Horseshoe and Pittsburg lakes. Its most sightly appearance is due to its situation at the foot of a beautiful limestone bluff indented by ravines and covered with forest. It has an area of between 1 and 2 square miles. It is one of the leading pleasure resorts for the people of St. Louis, being but 15 miles from the center of the city.

On the southeast side of the river opposite St. Charles, and just north of the area mapped, is a distinct terrace. It is typically developed at Bonfils Station, where a cut 25 or 30 feet deep is made in its edge by the grade of the St. Louis and St. Charles Electric Railroad. Its height here is fully 40 feet above the flood-plain, though not more than 30 feet above a lower terrace which is likewise continuous for a long distance and is followed by Taussig avenue. The lower terrace, so far as can be seen, is composed entirely of alluvium. A quarry in the upper terrace shows that it is composed of the St. Louis limestone. Its edge therefore bears the same relation to the narrower trough cut to a lower level, which the bluff itself bears to the Missouri trough as a whole. A ridge of loess follows the edge of the higher terrace rising from 20 to 25 feet above the general terrace level.

THE MERAMEC TROUGH.

While the Meramec river is not to be compared in size with the Mississippi and Missouri, its trough has all the characteristics described above for those of the larger streams. Its flood-plain has the same topography, is from 1 to 2 miles wide, and is limited by abrupt bluffs as high as those of the Mississippi. The fall of the stream is a little more than 6 inches per mile or about twice that of the Mississippi. In this, as in other respects, the Meramec is to be classed with the larger streams rather than with the smaller.

In and near the area mapped, the Meramec trough is carved in rocks of Ordovician and Carboniferous age, and its bluffs show outcrops of all the formations described on pages 10 and 11. The loess is much thinner than near the great streams and the steepness of the Meramec bluffs had allowed most of it to be washed away. These bluffs are also much cut by ravines, adding another condition favorable to rock exposures.

A noteworthy feature of the bluff near Valley Park consists of two long ridges or tongues projecting from the upland into the flood-plain. One of these extends a mile southwestward from Keyes Summit, between the flood-plains of Grand Glaise creek and Meramec river. A consideration of the normal development of valleys (See p. 34) will show that aside from its narrowness, there is nothing exceptional in this ridge lying between two valleys. A ridge south of the river leaves the bluff 1 mile south of Valley Park and extends northeastward. Its very steep northwestward face is the normal bluff of the Meramec while its long gentle slope to the southeast almost agrees with the local dip of the strata. The open valley of the small stream on this side is not exceptional. The fortunes of river meandering have so located the Meramec bluff that a continuous ridge is left, striking in its appearance but not exceptional in its origin.

NARROW VALLEYS.

Troughs of streams smaller than the Meramec, with the exception of certain parts of the lower course of the Des Peres do not show a sharp line of division between bluffs and flood-plains. The steep slope of the former merges into the horizontality of the latter by a curve, giving to the trough a U-shaped cross section (Fig. 3b). The larger of these valleys are indeed broadened by meandering; and, hence there has been undercutting of bluffs; but except where the small streams now follow the foot of the bluff, the washing or slipping of the loess has caused a merging of the bluff slope with the flat.

The smaller streams which are actively cutting down their channels and whose grade is not yet low enough to admit of any considerable meandering, run in troughs whose sides are convex upward (Fig. 3a), the steepness of the sides increasing as the axis is approached. This is also the general form of the still smaller valleys which are not occupied by permanent streams, though landslips in the loess or gullies with their correlative alluvial fans may locally alter the form. These smaller valleys are commonly cut entirely in the loess. They are indeed frequently deeper than the thickness of the latter, but most of them follow lines

Panorama northwest of Collinsville, Illinois, looking north and northwest.

Panorama northwest of Collinsville, Illinois, looking north and northwest.

Flood plain of the Mississippi, northwest of Collinsville, Illinois.

along which the surface of bed rock itself is lower; that is they follow approximately the lines of drainage which existed previous to the deposition of the loess.

Dependence of Topography on Underlying Rocks.

From what has been said it appears that there is a very close relation between the topography and the underlying rock formation. Where this rock is the St. Louis limestone, sinkholes frequently abound and so dominate the surface forms that drainage valleys do not appear. Where the smaller valleys are cut entirely in the loess, their side slopes are convex upwards, being often sharply incised and clearly delimited from the surrounding upland. On the shales of the Coal Measures, valleys of intermediate size have a U-shaped cross section and produce a beautiful rolling topography. These contrasts may sometimes be seen within short distances. For example that part of St. Louis which stretches southeastward from Forest Park is underlain by Coal Measures shales (See Geol. map, Pl. 18) and is characterized by open valleys and flowing curves, while around its edges the area underlain by limestone is closely perforated by sinkholes.

The Upland Surface.

SKY LINE.

The upland is the major topographic feature of the region and the standard of reference for the others. It is nowhere represented by a broad flat and rarely by a flat area as large as a single farm. It is not perceived at close range because its remnants are so narrow, being generally mere ridges between adjacent valleys. On a general view, however, it is seen that the larger of these ridges all rise to about the same height. The sky line is therefore nearly flat (Pl. 8). This general evenness of sky line in central and eastern United States is so common that, except from the geologist, it fails to attract attention. It is, however, the great dominating topographic feature, and without a clear perception of it, the history and significance of the valleys which indent it cannot be understood. Like the air, the medium in which and by which we live, this most widespread and most important topographic feature is liable to be taken as a matter of course, and thus to escape observation.

ELEVATION AND SLOPE.

The height of this upland 20 miles west of St. Louis is about 750 feet. In and around St. Louis it is 200 feet lower. Between these places the eastward slope is gradual, and, so far as known, nearly uniform. Around Belleville, Illinois, the height of the upland is about the same as at St. Louis. In this vicinity are the largest nearly level remnants of the upland. The continuation of the eastward slope of the upland east of the Mississippi is not clear.

EXCEPTIONAL ELEVATIONS.

Isolated Hills.—The eminences rising above the general level are generally so broad and low that the name hill is scarcely applicable. Near Stratmann, about 10 miles west of St. Louis, is a rise of from 50 to 75 feet above the general level over an area a mile or more in extent. There is a similar swell 2 miles farther north and a much more distinct one (because narrower, more abrupt and equally high) 2 miles northwest of Ballwin, which is nearly 20 miles west of St. Louis. All these elevations except the last have such gentle slopes that when viewed on the horizon they are distinguished with difficulty. It is these elevations which are capped with Lafayette gravels (p. 9).

Ridges on Top of Bluffs.—Another class of elevations rising above the general level of the upland is seen on the tops of the bluffs especially on the east side of the Mississippi. Here it is not uncommon to find a low ridge whose westward slope is continuous with the face of the bluff, rising from 20 to 40 feet above the upland 1 mile to the east (Fig. 2). Such a ridge is very apparent both north and south of Centerville, and like all such ridges is composed entirely of loess.

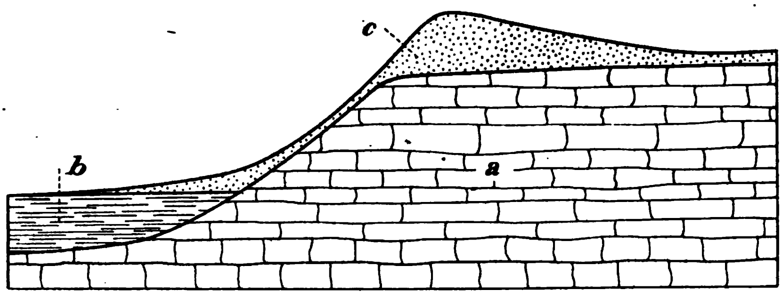

FIG. 2. Diagrammatic cross section of Mississippi bluff. *a.*—Rock with some glacial drift in its valleys; *b.*—River deposits; *c.*—Loess showing ridge on top of bluff and alluvial fans or slope of redeposited loess on flood plain.

SINKHOLES.

Parts of the upland underlain by the St. Louis limestone contain numerous sinkholes (Pl. 11). The smaller of the holes have a diameter of a very few rods. When this size they have nearly the shape of an inverted cone or of a funnel; with slopes as great as 10° or even 20°. Many of them are partly filled with water. The very different levels of the water in neighboring sinks show that they are frequently without a connecting passage. Their sides are generally completely loess-covered. Rock is rarely if ever exposed on slopes or bottoms.

These holes may be so closely congregated that a half dozen or more are found within a small field. In such cases they become the characteristic element in the topography, stream valleys being entirely wanting. An area thus characterized lies near the southern boundary of the area mapped, between Hickman Creek and the Mississippi bluff. (See geologic map, p. 18.) The southern part of St. Louis is similarly pitted, as is also a large area extending west from Jefferson Barracks.

Limestone sinks, one mile south of Stolle, Illinois.

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Occasionally the sinkholes attain large sizes and when their drainage is obstructed, hold lakes of considerable size. Spanish Lake, about eight miles north of St. Louis, is apparently of this origin.

CAVES.

Several caves of considerable size have been partly explored and it is quite probable that others exist. Cliff Cave in the St. Louis limestone two miles south of Jefferson Barracks, Mo., has a width near its mouth of about 50 feet and a height of perhaps 20 feet. This cave has been ascended for a considerable fraction of a mile. The small stream traversing it receives several tributaries from branches of the cave. Its total discharge at ordinary stages is probably less than 1 cubic foot per second. It carries much chert gravel, the mechanical wear by which has aided materially in enlarging the cave.

Near Brooksville, St. Clair County, Ill., a much larger cave is entered by a vertical descent of 80 feet from the bottom of a large sinkhole. The maximum width of this cave is at least 50 feet, and its height averages about 20 feet except where waters descending from sinkholes above have dissolved out arches or domes reaching to a height of sometimes 40 or 50 feet. The length of this cave actually explored is limited to about 3 miles, but the total length is probably several times that amount. It is joined by several tributaries bringing additions to the stream which has a considerable fall in an easterly direction. At the lowest point explored this is a swiftly flowing stream perhaps 1 foot deep and 6 or more feet wide. It carries much gravel composed of the chert which was originally embedded in the limestone, before the latter had been dissolved or worn away. At intervals there are found great cones or banks of loess which appear to have descended through sinkholes overhead.

Immediately east of the Mississippi flood-plain and south of Prairie du Pont Creek, sinkholes have an extraordinary development. Much of the water thus collected moves westward as a strong stream through a passage which terminates in the vertical bluff about 50 feet above the flood-plain, making the "Falling Spring." The origin of caves and sinkholes is discussed on page 18.

DRAINAGE.

The drainage of the entire region is to the Mississippi River. The drainage from about one-sixth of that portion of the area lying in Missouri reaches the Mississippi by way of the Missouri, and from about one-eighth by way of the Meramec. On the Illinois side no considerable tributaries intervene except in the extreme southeast corner in the immediate vicinity of Belleville, where the drainage is first to the Kaskaskia.

MISSISSIPPI-KASKASKIA DIVIDE.

The elevation of the water-parting between the Mississippi on the west and the Kaskaskia on the east is, in the vicinity of Belleville, about 560 feet. The trend of this divide is north-northeast. Along this line, and extending for 10 or 12 miles, there is a strip about one mile wide which is but little dissected, but the head waters of tributaries to the master streams are cutting back into it on both sides. West of Troy, Ill., this strip of relatively flat land broadens to 2 or 3 miles, affording a fair representation of the appearance of upland which comprised the entire area before the present valleys were cut. While the appearance of this bit of upland is fairly representative, it cannot be taken strictly as a sample of the former continuous upland, because of the deposit of glacial drift which may obscure or obliterate deep valleys in the pre-glacial surface.

From the divide west of Belleville, the tributary streams to the Kaskaskia and the Mississippi are of about equal length, and fall to about the same elevations, but almost the entire fall of the westward flowing streams is within 6 or 8 miles from the headwaters, while that of the eastward flowing streams is distributed throughout their entire length of about 20 miles. The headwater valleys of the former are correspondingly steeper and more sharply incised beneath the general level.

STREAMS FLOWING WESTWARD TO THE MISSISSIPPI.

Upper and Lower Courses Contrasted.—Streams flowing westward into the Mississippi have their upper courses in the uplands while their lower courses cross the flood-plains of the Mississippi. The characters of these two parts of each stream are sharply contrasted. The upper courses are in narrow, often V-shaped valleys, though the larger ones are now cutting down so slowly that their valleys are assuming a U-form (See p. 36). The fall of even the largest of these streams is from 10 to 20 feet per mile; that of the smaller tributaries may be two or three times as great. Streams in still steeper valleys are generally intermittent. Both the main streams and their tributaries are able to transport the largest stones found in the drift; sometimes bowlders several feet in diameter. Small tributaries are so numerous that practically the entire area is composed of valley slopes.

These same streams are changed almost beyond recognition in the broad flat flood plain of the Mississippi. No tributaries are received which originate on the flood-plain. The fall is but a few inches per mile. The same stream, which in its rapid flow in the upland could be stepped across, becomes sluggish, deep and wide, needing substantial bridges. The bowlders in the channels among the hills have disappeared, and their place is taken by nothing coarser than gravel, generally by sand and mud. The narrow valley 100 feet or more in depth and secure against overflow except along a narrow belt, has given way to a canal-like channel so little below the surface that a rise of a few feet causes floods which extend back miles from the channel. Finally, the banks which east of the bluff are firm and dry, bearing forests characteristic of the hills, have in many places become swampy and support a corresponding vegetation.

Cahokia-Prairie du Pont Divide.[1]—The flood-plain area east of the Mississippi is about equally divided between the two basins, the Cahokia on the north and the Prairie du Pont on the south. The divide between them is vague and uncertain, because certain areas drain now to one creek and now to another, according to the stage of the water at different places, or according to the open or closed condition of their changing channels.

A faint swell or exceedingly flat ridge crosses the flood-plain in an east-west direction just south of the boundary between Madison and St. Clair counties. In the main it is followed by the Vandalia and the Baltimore & Ohio railroads. The rest of this ridge is about 418 feet above sea level or 38 feet above low water mark of the river at St. Louis. Toward the north the level falls about 12 feet within a mile, to the swamps along Cahokia Creek. Such a slope is perceptible only with instruments, or by noting the behavior of the water. The slope to the south is less than 1 foot per mile.

While this ridge is relatively definite, it does not at all times constitute the divide. Schoenberger Creek which emerges from the bluff at French Village is so liable to obstruction by sediment that it flows sometimes to the north into Cahokia Creek and sometimes to the south into Pittsburg Lake and the Prairie du Pont. In 1903 when the U. S. topographic survey was made (Pl. 18), the greater part of the water was flowing into the northern or Cohokia basin. Caseyville and Canteen Creeks, emerging near Caseyville, always send their waters to the Cohokia, but sometimes by a direct northerly course, while at other times they first flow south-

[1]For information concerning exact levels, discharge, area of basins, etc., see Helm, Edwin G., The Levee and Drainage Problem of the American Bottoms, Journal of the Association of Engineering Societies, Vol. XXXV, No. 3. Sept., 1905, pp. 91-117.

west to Spring Lake, thence into Schoenberger Creek, and ultimately to the Cohokia north of East St. Louis. At the time of the topographic survey they flowed in a northerly direction, joining the Cohokia near Monks Mound.

Cohokia Creek.—Cohokia Creek flows over the Mississippi flood-plain for a distance of about 20 miles if measured in a direct line; its turns and meanders make its full length nearer 30 miles. Much of its course is bordered by swamps. It has a fairly uniform fall of about 1½ feet per mile. It receives a number of tributaries which emerge from the bluffs, but no distinct streams which originate on the flood-plain. Far the larger part of its water is likewise received from the uplands where its drains an area of 315 square miles, its total drainage area in the bottoms being 93 square miles. Sudden and abundant rains on the uplands, therefore, tend to flood East St. Louis. Danger from this source would be much greater were it not for the basin of Horseshoe Lake over whose area of nearly four square miles, surplus waters may spread, thus moderating the flood. It has been calculated[1] that in a flood of Cahokia Creek in 1904, two billion cubic feet of water, which would otherwise have flooded the land, were thus held back. As this was about one-half of all the water which fell in an excessive downpour on the entire drainage basin, the significance of such lakes in preserving the higher ground of the flood plain from inundation is seen to be great. The most destructive floods originating in the Cahokia basin increase the normal depth of water in the lake 6 to 10 feet. The highest and most destructive floods at East St. Louis come from the Mississippi, but the city would probably suffer oftener from the floods of the Cahokia than from those of the Mississippi, were it not for the conservation of water in the Horseshoe Lake Basin.

Prairie du Pont Creek.—As compared with the Cahokia basin, that of the Prairie du Pont has a relatively larger area of lake surface and swamp. The fall of the main creek is so small that it is difficult to determine the natural drainage line, if there be one. The drainage area on the upland is relatively small. This fact, taken with the large lake surface over which storm waters may expand, makes the liability to local floods much less than in the northern basin.

Chutes and "Dead Creeks."—Near the river are a number of channels roughly parallel to the river and generally open to it at both ends. These are known as *chutes*. Their currents are relatively sluggish, and they are liable to obstruction at both ends by deposits of mud. When long obstructed they become filled with mud and vegetation. Between these and the swales which characterize the whole flood-plain (See p. 14) there is no sharp distinction. The "Dead Creek" which extends from East St. Louis to the village of Cahokia, is an abandoned channel, which may at one time have carried the waters of Cahokia Creek.

DRAINAGE WEST OF THE MISSISSIPPI.

The drainage on the west side of the Mississippi has fewer peculiarities than that on the east side. It has throughout about the same character as that of the upper courses of the streams in Illinois described above.

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[1]See Helm, E. G., loc cit.

Divides.—The minor divides separating the basins of the Missouri, Meramec and Mississippi, are less in contrast with the surrounding country than is the Mississippi-Kaskaskia divide near Belleville. With the exception of a few inconspicuous hills the elevation of these divides is that of the general upland. That between the Mississippi and Missouri systems stretches in an irregular line from near Kinloch on the northern edge of the area, southwestward to near Altheim on the western edge. It embraces the high ground near Stratmann, and from that place west to Creve Coeur is followed by Olive Street. The Missouri-Meramec divide carries the inconspicuous hills near Altheim from which place it extends southwestward and is followed by prominent roads for many miles. The high hill northwest of Ballwin and the elevated tract at the head of Glencoe Gulch are on this line. The Meramec-Mississippi divide extends southwestward from Altheim and embraces the relatively high and relatively flat area around Kirkwood.

Streams Entering the Mississippi.—The drainage directly into the Mississippi from the west is chiefly through the various branches of the River des Peres. These show a noteworthy tendency to rectangular turns, the prevailing directions being southeast, northeast, and southwest. This is well illustrated in the bend of Gravois Creek northwest of Jefferson Barracks; again in the bend of the River des Peres around Forest Park, and still again at the junction of the north and west branches of this river at Greenwood. In a very general way these directions are the same as those which would be favored by the structure of the underlying rocks (See p. 4). Doubtless to some extent the stream directions are dependent on the structure, but the streams are too large and too old to show a close correspondence. Moreover the covering of loess over which the streams took their present courses has rendered the streams independent of rock structure, except in so far as the valleys antedating the loess have been preserved.

The fall of the River des Peres and its larger branches in the last 20 miles before joining the Mississippi averages about 5 feet per mile. The upper courses of the streams, where permanent, have slopes ranging from 20 to 40 feet per mile, while the still steeper valleys nearer the divides are occupied by temporary streams.

Streams Entering the Missouri.—Creve Coeur Creek, with its chief tributary, the Feefee, enters the Missouri after a course very similar to that of the creeks entering the Mississippi from the east. The course through the Missouri flood-plains is, however, relatively short and only partly comprised within the limits of the St. Louis quadrangle. Creve Coeur Lake is now an expansion of Creve Coeur Creek through occupying an abandoned channel of the Missouri.

The upper courses of these streams are somewhat steeper than those flowing east into the Mississippi. They are therefore cutting down their valleys somewhat more rapidly. The effect of this may be observed west of Stratmann where the country north of Olive Street draining to the Missouri is more hilly than that to the south which drains to the Mississippi.

Streams Entering the Meramec.—The Meramec River flows through the higher part of the upland and receives a number of short tributaries. Grand Glaise Creek on the north and Fenton Creek on the south are the longest. These have a moderate fall and wide open valleys. The others, like the secondary tributaries of these two, flow in narrow, steep valleys often gully-like at their heads. It is noticeable that the divide between the Meramec and Mississippi Rivers is about four times as far from the latter stream as from the former. The tributaries to the Meramec have a correspondingly greater fall for the two master streams are at about the same level. There is a corresponding contrast in the forms of the valleys, those of the Mississippi tributaries being wide open and of gentle slope as compared with the gully-like forms of those in the Meramec bluff. Opposite the village of Fenton several streams of considerable size emerge from the bluff and are lost on the flood-plain before reaching the Meramec. This is doubtless due to the constitution of the plain (See p. 5), whose highly permeable character allows all the waters of these tributaries to percolate.

POORLY DRAINED AREAS.

From the above description of topography and streams, it appears that there are in this area a number of spots having few streams and little run-off. These fall into four different classes: (1) Those portions of the Mississippi flood-plain in which the fall is insufficient for the development of small streams, and where the surface of the ground water over wide areas is close to that of the ground; (2) That portion of the Meramec flood-plain where all surface waters are absorbed into a highly porous alluvium; (3) those parts of the upland characterized by sink-holes which convey the surface waters to underground channels; and (4) portions of the Mississippi-Kaskaskia divide stretching northeastward from Belleville, both sides of which are bordered by gully-like valleys leading in opposite directions but whose heads have not yet met.

PRINCIPLES PERTAINING TO CHANGES NOW IN PROGRESS.

The processes by which land forms are made and continually changed are well illustrated by many phenomena within the area here described. The general principles underlying these may be conveniently grouped under three general heads. (1) Weathering or the breaking down of rocks. (2) Transportation or the movement of disintegrated rock, generally through the agency of water, and (3) Seedimentation, or the laying down of mud, sand, etc., generally after transportation for a considable distance.

Breaking Down of Rocks.

Solid rocks are wasted away by a variety of processes. Some of these merely break up the ledge or stratum into large fragments, and these again into smaller pieces without changing their nature or constitution, so that in the end, each fragment is in all its properties identical with the original ledge. Such changes are purely physical and, at most, only disintegrate the rock but do not decompose it. Other agencies actually decompose the rock, changing its chemical constitution as well as destroying its integrity. Various weathering agencies may work on the same rock simultaneously, or the rock may consist of several different kinds of material, each distributed throughout the mass. One or more of these constituents may decompose, allowing the others to fall apart. Thus, while the several agencies of weathering may readily be distinguished and discussed separately, the actual process which causes the disintegration of any one rock may be, and usually is, complex.

SOLUTION AND CHEMICAL CHANGE.

Some rocks, like salt, are readily dissolved in water. Others, like limestone, are dissolved slowly by ordinary terrestrial waters after a slight chemical change. This process is nowhere better illustrated than in the vicinity of St. Louis and adjacent parts of Illinois.

Caves and Limestone Sinks.—Should the limestone bedrocks suffer equal wasting over a wide area, the result would not be known by any striking topographic form. In actual experience, the solution is largely concentrated along fractures, often at a considerable depth below the surface. Thus caves are produced. Through such passages the ground water is able to move its streams which are often swift, instead of percolating slowly as it does through other rocks and soil. The passages are therefore further enlarged by the wearing effect of these streams which may carry sand and gravel, just as is the case with a valley on the surface.

Limestone sinks or sinkholes (See p. 18) are caused by the dissolving action of water descending from the surface through joints or cracks to some kind of passage below. Sometimes this passage is a large cave, but it should not be inferred that a sinkhole always, or even generally, indicates the existence of a cave below. Some have supposed that such holes are frequently due to the falling in of the roof of a cave, but this is probably rare in this region and is not known to be well illustrated in the area mapped for this report. Where the passage below or the entrance to it is stopped, ponds may be formed. Where sinkholes are numerous (See topographic map, Pl. 18) they receive all the water falling on the surface, and continuous surface streams are not found.

Other Chemical Changes.—Aside from the processes involved in the solution of limestone, the only chemical process much in evidence is oxidation. The oxygen of the air in the presence of the moisture of the earth affects even the limestones. The effect may be seen in any quarry or ledge. The rock is weakened and its lively gray color is changed to a duller yellow. The substance thus sought by the oxygen is iron and the yellowish color of the weathered rock is due to iron oxide (iron rust). Many of the rocks of the glacial drift (See p. 8) contain far more iron than the limestone, and are consequently more subject to oxidation. In many cases their color is completely changed and their coherence entirely lost.

Various mechanical and chemical processes, one of which is oxidation, have changed the character of the upper 3 or 4 feet of the loess. On account of these changes the topmost layer is darker in color and also stiffer than the main body of the loess.

MECHANICAL CHANGES.

Frost.—Of the agencies which merely break the rock to pieces but do not change its nature, the most prominent in this region is "frost," or more properly, frozen groundwater. Its effects are keenly realized along the railroads which follow the river at the foot of the almost vertical bluffs. Great blocks of rock frequently fall from the faces of such bluffs, being pried loose by the expansion of ice freezing in the cracks. The effect of this process continued throughout many years, is seen in various places, as for example in the great bank or *talus* of limestone blocks which rests against the foot of the bluff south of Prairie du Pont Creek.

The work of freezing water is not limited to steep bluffs though its effects there are more spectacular than elsewhere. Everywhere, as deep as the "ground freezes," the effect of freezing in cracks and pores is to rupture the rock and to open the way for the agents which act chemically. Nor is the work of frost restricted to fresh and solid rocks. It continues with equal importance in weathered or "rotten" rocks and even in soil.

Heat and Cold.—Another agent which helps to open cracks is the sun's heat. By causing expansion during the day and in summer, associated with contraction at night and in winter it is an effective agent, but its effects in this region are not so evident as are those of freezing.

Plants.—The work of roots in helping to break up rocks in strikingly manifest at many places on the bluffs where trees grow almost without soil, their roots entering crevices in the rock which are slowly widened as the roots grow. It may, however, be said of this agency as of many others; that its more spectacular effects are not its most important work. For every block of rock actually pried off by the expanding root of a tree, a thousand crevices are slightly widened so as to admit more freely the agents of chemical decomposition. Again, the work of tree roots which challenge our notice, is probably small as compared with that of humbler forms of plant life like lichens. Whenever the face of a bluff is blotched with green or gray patches, the minute rootlets of lichens are engaged in a work whose aggregate effect greatly exceeds that of tree roots. In still further contrasting the more noticeable effects with those which escape popular notice, it might doubtless be shown that the aggregate of all the mechanical effects of growing plants is small in comparison with the chemical effects due to the products of their decay.

Sapping.—An important factor in the breaking up of rocks is the indirect effect of the disintegration of their neighbors. Where the edges of nearly horizontal beds are exposed, and one of the lower members is easily worn or weathered away, the effect is to withdraw support from the stronger rocks above, which then break off in a vertical face. This process, known as sapping, has caused many steep hillsides south and west of the area studied. Near Kimmswick, Mo., shales underlie strong limestones, while farther south, as well as west near Pacific Junction, the very soft St. Peters sandstone used in glass making is overlain by strong limestones. In both cases the arrangement of the materials is reflected in the shapes of the hills.

Movements of Rock Waste.

All the processes described above, which break down rocks, tend to bring them into suitable condition to be transported. In fact, the whole complex process of weathering, may be viewed from a physiographic standpoint as merely preparation for transportation. This latter process, like the former, is effected chiefly through the agency of water, though to a less extent by wind, and in a slow way by gravity without the immediate aid of either water or wind.

The word erosion which has come to be used in a somewhat general sense, may be taken to stand for the aggregate of all processes whose effect is to pick up and remove surface materials. Thus used, it includes all forms of transportation together with the processes of picking up material by the agents of transportation.

CREEP.

A quiet process attracting little attention, but omni-present on slopes, is the slow creep of disintegrated rock and soil under the influence of gravity. The steady and uniform pull of this force would not of itself set the mantle rock in motion, but during any slight disturbance or rearrangement of particles a majority of them come to rest a little down hill from their former position. Such rearrangements result from such alternating processes as freezing and thawing, warming and cooling, wetting and drying, the creeping of worms and the movement of roots as the trees above sway in the wind. Nothing in the process attracts attention, but its results are so common that a landscape of steep slopes would look strange without them. Among these is the tendency of trees to lean down hill, a phenomenon so nearly universal that it is not fully realized until a picture is seen in which the trees along a ravine are made to stand vertically. The ground near the surface being most subject to such mild agitation, moves most rapidly carrying with it the base of the trunk, while at greater depths the roots retain almost their original position. Thus a rude measure of the velocity of creep is afforded by the degree to which trees lean down hill.

Since phenomena like this are as widespread as steep slopes, individual examples need not be cited, but they are found in special abundance and beauty on the steep slopes of the Mississippi bluffs and in the ravines which indent them. The character of the loess is favorable to this process, so much so that the tendency must always be reckoned with in determining whether a body of loess found on a slope, is or is not in its original position.

UNCONCENTRATED WASH.

The wash by surface waters before concentrating into separate streams differs from creep in affecting surface particles only. Like the latter it is intermittent, though its periods of activity differ from those of creep. It is like the latter in its quietness and liability to escape notice, as well as in the greatness of its effects. Water thus moving is not to be thought of as a sheet of uniform thickness, but rather as a great web or net of small rills which are not constant in position and none of which pursues its course very far without further subdivision or union with others. Even where grass is absent these rills do not cut channels because their small power is all used in transporting the sediment with which they are loaded.

Among the familiar effects of such wash is the filling on the uphill side of obstacles such as buildings, boulders and (in regions where they exist) stone fences. The effect on a plowed field after a rain is often seen in the filling of small depressions, leaving in their place flat surfaces covered with a web-like pattern of rill marks.

Such rills, whose work is classed as unconcentrated wash, bring to the streams a large part of the mud which great streams like the Mississippi carry in such enormous quantities. The exact topographic

A—Valley in loess, one and one-half miles west of Imbs, Illinois, looking southeast. Shows characteristic shape with side slopes convex upward.

B—Valley in loess, one mile east of Ballwin, Missouri. Shows characteristic shape with side slopes convex upward.

effect of such wash is not easily stated, but without it the shapes of valleys, especially their borders and heads, would differ greatly from the forms which are familiar. There is reason to think (See p. 57) that the level of the entire upland in and near the area here described has been cut down fully 50 feet by such erosion without valleys.

TRANSPORTATION IN SOLUTION.

It was seen above that the weathering away of limestone is accomplished largely by dissolving it. Much of this and of many other substances is thus transported to the sea. Most waters from rivers and wells in northern United States are known as "hard." This is because of mineral matter (chiefly calcium carbonate, the substance of limestone) in solution. It has been computed that the dissolved material annually delivered by the Mississippi to the sea would, if converted into the form of rock, cover one square mile more than 100 feet deep. Its weight is more than one hundred million tons. Probably half as much passes by St. Louis each year. While on the one hand this implies a great wasting of limestone and other soluble rocks, it is, on the other hand, supplying the sea with the material from which new limestone is being made. The material now in solution becomes solid again when taken by animals to build their shells. From these shells new limestone is made.

TRANSPORTATION IN SUSPENSION.

A second way in which the waste of rocks is transported to the sea is by carrying it is suspension. In this condition the individual particles of sediment are very small, and remain suspended in the water as mud. Each particle is constantly being drawn downward by gravity and would ultimately settle if the water were at rest, but by the constant commotion of the water it is repeatedly carried upward.

Sand-boils.—From any bridge over the Mississippi, or better still from the deck of a steamer, the upward currents of the water may readily be seen making the so-called "sand-boils" or "mud-boils." These are nearly circular patches from a few feet to a few yards in diameter within which the water is evidently rising, carrying upward so much sediment that, in contrast, with the surrounding water, these "boils" are distinctly brown. Such localized upward currents, and others which can not be detected by any surface phenomena, may keep a single particle of mud in suspension continuously from St. Louis to the Gulf of Mexico. More often, however, one particle probably comes to rest many times within that distance, and may rest at some places for years or even centuries.

Contrast of Streams.—The sediment carried in suspension past St. Louis is derived in large part from the Missouri river rather than from the upper Mississippi. Below the junction of these streams, their waters may remain to a large degree separate for a number of miles, occasionally as far south as St. Louis, the dark brown silt-laden water of the Missouri on the west side being separated by a somewhat definite line from the lighter colored and more transparent waters derived from the upper Mississippi. This phenomenon is quite as striking below Cairo where, at ordinary stages of the rivers, the light yellow waters of the Ohio are sharply separated from the relatively brown and opaque waters of the Mississippi.

The amount of sediment carried by the Mississippi in this manner greatly exceeds that transported by other methods. It has been calculated with some approach to accuracy that all the sediment carried by this river to the sea, about eight-ninths of which is mud in suspension, would in one year cover a square mile, 268 feet deep.

TRANSPORTATION ON THE BOTTOM.

Effect of Velocity.—All that portion of a river's sediment which is composed of particles too large to be held in suspension, is rolled or pushed along the bottom. While in supporting sediment in suspension, agitation is the chief requisite, the onward velocity of the water at the bottom is of prime importance in transporting sediment on the bed of the stream. The velocity of streams at their bottoms is much less than at the surface, but all are swifter in flood than at ordinary stages. In this way streams of even moderate swiftness may in flood push forward cobble stones and small bowlders. Thus the large stones ordinarily found at rest in the channels of Prairie du Pont and other creeks in the Mississippi bluffs are moved forward in times of flood.

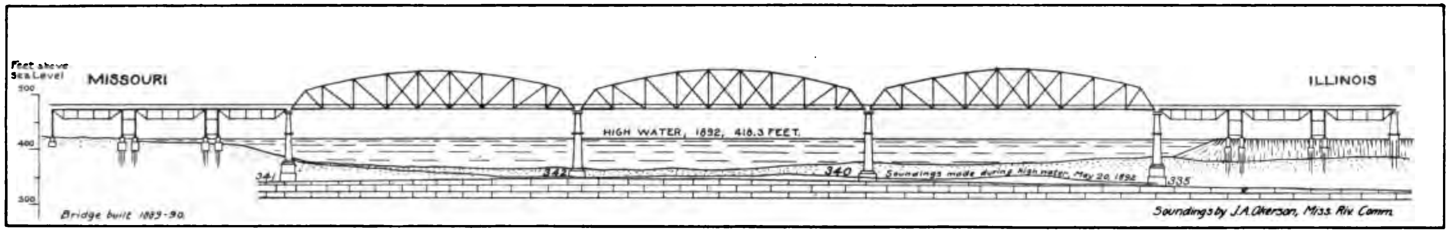
Scour During Floods.—The material urged along the bottom of the Mississippi at ordinary stages is mainly sand and small gravel. In great floods, however, this material is scoured to profound depths and the river occasionally moves it forward on the solid limestone whose surface is from 50 to 100 feet below the level of low water. (Pl. 14). Even at that depth the flooded stream still has the power to push forward with vigor its load of stones, some of which are bowlders of large size. The evidence of this is seen when the surface of this bedrock is laid bare in the building of bridges, and is found to be smoothed and polished, and composed of perfectly fresh rock.

When such scouring is in progress, all the gravel which is commonly found stratified between the bottom of the river and the surface of bedrock is being urged forward in a comparatively thin sheet over the limestone bed. It is not to be understood, of course, that such scouring takes place throughout the entire stream at one time. In any one flood, scour which reaches the bedrock at a depth of 50 or more feet below low water mark is a very local phenomenon. But even in this occasional way, the turn comes around to every part of the valley, and the thick sheet of gravel beneath the stream may all be moving intermittently toward the sea. In a like intermittent manner the rock trough may be deepening. These are believed to be the present conditions in the Mississippi trough.

The main distinction which the river makes at such times between large and small stones is in moving the latter at a faster rate. When the flood begins to subside and the velocity and power fall off, the largest

A—Meramec River at Glencoe, Missouri, looking east. In the process of meandering the stream is cutting the bluff at the left and building the shoal at the right.

B—Bank of Mississippi River above Cairo, Illinois, showing layers of silt laid down during overflow.



Scour at Merchants' Bridge, St. Louis, by flood of May, 1892. Above the Mississippian limestone on which the piers rest is shown the sheet of alluvium. The line of soundings shows the depth to which this was scoured out on May 20, 1892.

bowlders first come to rest, and then the smaller gravels. Hence when cut through in the building of bridge piers, the largest stones are found at the bottom. This is true not merely for the deposits immediately beneath the present stream, but elsewhere on the flood-plain, for it may be shown that all the deeper alluvium within the rock trough was laid in its present position by the stream which has successively occupied all possible positions on its flood-plain.

CORRASION.

VERTICAL.

If a stream has more power than is necessary to transport its load, it will move it forward at a rate depending on this excess of power. This rate is limited by, and never reaches, the stream's velocity. This forward motion wears the stream's bed, and thus tends to increase the amount of sediment. This wear is one form of corrasion, and tends to bring about a balance between a stream's power and its load by increasing the latter when the former is in excess. Corrasion in general, is the wearing effect of a stream on its channel, and is therefore a form of erosion. When acting in the way described, the chief cutting is at the bottom of the stream and therefore tends to deepen the channel. The deepening of valleys is therefore characteristic of streams which have an excess of power. Such streams are said to *degrade* their channels; that is, they are *degrading streams*. The effect of deepening is to make valleys steep and relatively narrow (Pl. 12 and Fig. 3a). Excess of power and steepness of sides is characteristic of the smaller valleys in the bluffs and to a large extent throughout the uplands of this area.

LATERAL CORRASION.

As corrasion embraces all the wearing effects of a stream on its channel it includes that done on the banks. Such lateral cutting does not imply that a stream has power to spare after transporting its entire load. On the contrary, it is most noticeable in streams whose load is so great as to prevent down-cutting. Such streams are apt to build deposits which turn the current somewhat against the banks. The effect of cutting away the banks is to embarrass the stream with a still greater load and require more deposit. Thus a stream engaged in lateral corrasion works its drift over and over, picking up and laying down the same material many times before its final deposition in a delta or elsewhere. In some streams the picking up process is in excess; in others the laying down process.

This process of lateral corrasion is one of the most important to be considered in the life of the Mississippi River. It is constantly at work and, to guard against its destructive effects, many millions of dollars are spent annually by the United States government in building revetments. The steepness of the bluffs is due to under-cutting at the base by the lateral corrasion of the river. (Pl. 13.)

Deposition of Sediments

In making the features which characterize this region, the depositional work of the streams is no less important than their erosional work. Deposition is always associated with some loss of power. This may result from an actual loss of a part of the stream's water, as illustrated in the region under consideration, only by the small streams which disappear by percolation in the Meramec flood-plain, opposite Fenton. Loss of power as illustrated here is almost always due to loss of velocity, which may be brought about in many ways. Streams which deposit in their channels more material than they remove are said to *aggrade* their channels, and are spoken of as *aggrading streams.*

ALLUVIAL FANS.

Except in the larger streams of this area, the most common condition under which velocity is lost is a change of slope. In descending a steep slope the stream uses power not needed for transportation, in corrading its channel and thus adding to its load. When it emerges upon a gentler slope its velocity and power are in part lost, and it must deposit a part of its load. This is especially true if the stream spreads out in a shallower and broader channel, for the more concentrated the stream the greater its velocity. Downward corrasion on the steep slope favors such concentration in a narrow channel. This advantage is lost on the flatter grade below, even before deposition begins. When the channel has been partly or wholly filled, the stream is still further spread, with a corresponding further loss of power. The result of aggrading its channel above the adjacent land is that the stream breaks over and takes a new course or subdivides until in the course of time it has flowed over and aggraded the slope in all possible directions from the mouth of the ravine.

The conditons here described are met in hundreds of short narrow gulley-like valleys throughout the area considered. The circumstances are especially typical in the ravines which indent the Mississippi bluffs. The little and often temporary streams in such ravines have abundant power and often cut narrow valleys whose sides increase in steepness from the top down to the stream. On emerging from the bluff upon the gently sloping flood-plain, material is dropped in the form of alluvial fans or sectors of low cones sloping in all available directions from the apex in the mouth of the ravine, where deposition begins.

Sometimes such fans or cones are found singly and are so well defined that the material of any one structure may be shown to be approximately equal in volume to that of the gully or ravine from which it was eroded. Oftener, however, such gullies are so close together that their attendant fans have not room to develop independently. When they are closely crowded, their lateral slopes may be lost, but the inclination outward from the hills is preserved, forming an inclined plane with a slope intermediate in steepness between the abrupt bluffs on one side and the flat flood-plain on the other. Such a feature has appropriately been called an *alluvial slope.*

A fine alluvial slope spreads westward from the east bluff of the Mississippi for many miles north of Pittsburg lake. It is formed not simply by a conjunction of definite alluvial fans built by the wash of gullies, but includes a large amount of material carried down from the bluffs by unconcentrated wash. Its slope is not noticeable to the unaided eye for more than a few hundred yards from the bluff, but its effect is probably felt for a mile or more in raising the otherwise flat flood-plain above the reach of the highest floods.

DELTAS.

Deposition also occurs where streams discharge into bodies of standing water or into more slowly flowing streams. The topographic form thus produced is the *delta.* This is not exemplified in a large way within the area studied but, for purposes of illustration, small but highly perfect forms may be found in the lakes on the flood-plains. Temporary deltas of perfect form are also made in the large streams.

SUBSIDENCE OF FLOODS.

In the two cases considered above, the change of carrying power is between one place and another and deposition is correspondingly local. During the subsidence of a flood, power is lost throughout the entire stream and deposition is correspondingly general. The contrast here is between one time and another.

Deposits from Suspension.—Deposition during subsidence of floods involves both material carried in suspension and sediments pushed along the bottom. The former are deposited as a fairly uniform sheet of mud over the area overflowed, but not within the channel into which the diminished stream retires. The great Mississippi flood-plain is in part composed of mud or silt laid down in this way. This is, of course, especially true of its superficial layers. At almost any place where the great river is cutting into its banks a passenger on the deck of a steamer may easily see that the upper 5 to 10 feet of alluvium is prevailingly silt in contrast with the lower layers which consist more largely of sand and gravel, (Pl. 13, B.)

Deposition from suspension is the main process by which the present lakes on the flood-plain are being filled. They are not subject to strong currents even when the flood is at its height and with the beginning of subsidence are soon left entirely stagnant.

Deposits at Bottom of Channels.—When the flood subsides and its velocity is reduced, much of the material moved along the bottom comes to rest. Sedimentation of this kind affects not only the regular channel but the temporary channels through which the river may flow over its alluvial plain. Sheets of mud deposited from suspension are, therefore, often traversed by a network of gravel bands. Where the floodplains are built mainly by overflow, and therefore of silt, such webs of gravel may be found at all elevations throughout the deposit even though it be hundreds of feet thick.

It has been pointed out above that the Mississippi during flood may scour its channel to great depths (See p. 30). The depth of deposit during subsidence is correspondingly great. The fact therefore that a river at ordinary stages runs over a deposit of 50 to 100 feet of sand and gravel is not to be interpreted as showing that the stream is failing to deepen its trough by corrasion.

DEPOSIT INSIDE OF MEANDER CURVES.

Probably the most abundant of all stream deposits are those made in the relatively quiet water on the bottom and banks on the inner or concave side of meander curves. These are made at all times and are independent of overflow. The rate of their making is, however, greatly accelerated by moderate floods such as approximately fill the channel. The material laid down is that which is being urged along the bottom. It consists in general of sands and gravels. These are built into a shoal, sloping streamward. Successive additions are put down in rude layers or strata whose dip is that of the surface slope (Fig. 6). The height of these deposits is that of the water surface so long as the stream remains within its banks. As the channel is shifted by lateral corrasion toward the convex side of the curve, this deposit of sand and gravel is broadened on the side toward the stream.

In the way here described, the entire area over which the channel is shifted, comes to be covered with a deposit whose origin is independent of overflow. In the case of most streams which overflow, this deposit is covered by successive layers of mud laid down during overflow as described above.

THE MAKING OF VALLEYS.

CONSEQUENT STREAMS AND VALLEYS.

In considering the origin of valleys, two widely different and sharply contrasted sets of conditions present themselves. The first is that of an accumulated volume of water seeking an outlet to the sea by the lowest possible route. Such a route would be determined by selection from the source downward, and the valley which would later be eroded along that route would be the natural consequence of initial slopes. Such valleys and streams are, therefore, spoken of as *consequent*. The Niagara and St. Lawrence rivers whose histories are familiar, are good examples. Parts of the Missouri and Ohio rivers, which where crowded southward to their present positions by the continental ice cap, and parts of the Mississippi displaced by the same means, are of the same class. Rivers like the Potomac and the James which cross the Coastal Plain agree with those named in this essential fact that they were obliged to hunt their way across a land area, choosing their course from the head seaward.

SUBSEQUENT STREAMS AND VALLEYS.

Origin.—In sharp contrast with streams and valleys of the above type, are those which begin at the lower end and grow headward. In this case the initial condition is one of unconcentrated wash. Somewhere on the slope so washed (it may be near the foot), the concentration of water becomes sufficient to cut out a gully. This gully at first carries nothing but storm waters and hence has an intermittent stream. Repeated rains, however, cut it down to the surface of ground water and when its channel indents that surface, there is constant flow.

Down-cutting.—Down-cutting may go on rapidly for a time, but its effect is to diminish the slope from any one point to the point of discharge. This slope cannot be reduced beyond a certain degree for the material constantly washing into the gully must also be washed out. So long as down-cutting is active the side slopes are steep and may increase in steepness toward the axis (Fig. 3, a.)

Widening.—Since the effect of cutting down the axis is to increase the steepness of the sides, the washing and wasting of these is thus favored and the gully is thereby widened. The deeper and wider the gully becomes, the longer are its slopes and the more material is washed from them into the channel. In the early stages, while these side slopes are short, the deepening process has the advantage and the gorge is accordingly steep. Later the wasting of the sides overtakes, as it were,

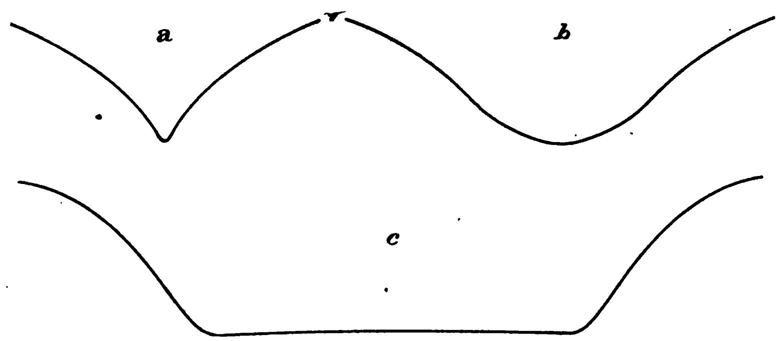


FIG. 3. Cross sections of valleys. *a.*—Young valley with stream (or intermittent stream) cutting down rapidly. *b.*—Older valley with downcutting retarded but without significant flood-plain. *c.*—Older valley with flat bottom, (flood plain) and bluffs.

the corrading of the axis and there may come a time when the power of the stream in the axis is all used in transporting the sediment furnished to it by the wash of its sides and head. The resulting inability to cut down the channel is reflected in the slopes of the sides which become constantly more gentle. If the new valley is alone in a considerable area it widens indefinitely, but if it has neighbors, its own slopes and those of its neighbors ultimately meet and form a sharp divide. The slopes of each can then continue to be cut lower but no further widening of the valleys is possible.

Headward Growth.—For reasons similar to those which cause a valley to widen, it may also be elongated headward. The essential fact in both cases is that the cutting down of the foot of a slope steepens it and thus promotes erosion. Only, this erosion at the gully head is more rapid than that on its sides, because more water comes in at the head. The headward growth of a valley is subject to the same limitations as its widening. So long as it exists alone such headward growth may go on indefinitely though at a constantly diminishing rate. Sooner or later, however, it meets other valleys leading in the opposite direction and a ridge-like divide results. The two valleys or streams are then in *headwater opposition*. Both slopes may then be cut lower, but neither valley can elongate headward except at the expense of the other.

Branching.—For various reasons the headward growth of a valley is not generally confined to a single line. More than the average supply of water may enter from several directions, as determined by initial slopes which, although far too gentle to constitute stream valleys, are sufficient to determine the direction in which gully heads shall grow. If the young valley is cutting in rock, joint planes may offer lines of weakness along which the gully head may advance, even without any initial slope. Moreover as soon as a trench is made by erosion, its side slopes may be considered in the same light as the original slope on which the parent gully formed, that is, they themselves will be subject to gullying whenever the water descending them reaches a certain degree of concentration. For all these reasons it will be seen that subsequent valleys are rarely found simple and solitary. If given sufficient time they increase in number, length, width and complexity, until the original land surface has disappeared and the entire area has become valley slopes.

CROSS SECTIONS OF VALLEYS.

Repeated allusion has been made above to the effects of certain processes on the steepness of slopes. These find their expression in the cross section and profile of the valley. In general, the shape of the cross section depends on the relative vigor of two processes, corrasion of the channel and erosion of the slopes. The former tends to make the valley relatively narrow and deep. This is the case with young valleys. The latter tends to make the valley wide and relatively shallow. This shape characterizes old valleys. If the vigor of down-cutting be great as compared with widening, the side slopes will increase in steepness as the central channel is approached, that is, they will be convex upward (Fig. 3, a). With less proportionate vigor of down-cutting this convexity disappears. Valleys of such form are commonly spoken of as V-shaped. With still less vigor of down-cutting the side slopes become compound curves, steepest at intermediate heights and flattening as the axis is approached (Fig. 3, b), that is, the valleys become U-shaped. It is not to be understood that streams in U-shaped valleys are as a rule aggrading their channels nor even that they have ceased to degrade.

MEANDERING.

Cause.—At any fortuitous curve or turn, the stream's power is to some extent concentrated on the outer or convex side of the channel, leaving the water on the concave side with less than its average velocity. At such a time, if the average down-cutting power of the stream be sufficiently small in proportion to its load, its power on the inner side of the curve becomes actually deficient, and deposition takes place in the

Meander of the Mississippi River above Greenville, Mississippi. From map of Engineer Office, U. S. A., St. Louis, Mo.

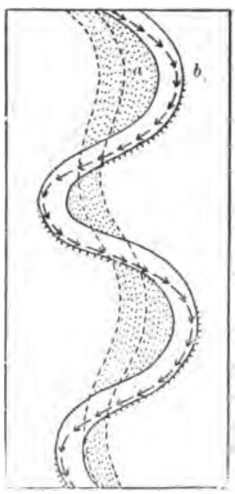
channel against the inner bank (See p. 34). The effect of this is to narrow the stream, whose power is then still further concentrated against the outer bank. The shifting of the channel which is initiated in this way tends to make curves of somewhat uniform sharpness, their radii depending on the volume and power of the stream and the nature of its load. When well developed, such curves are called meanders. (Pl. 15.) It is to be observed that the conditions of meandering are not limited to aggrading streams, or even excluded from degrading streams. The one essential is that in going around a curve the distribution of power shall be such that the power on the inner side of the curve falls below what is necessary to carry the load; that is, the load must be sufficiently near the stream's capacity so that it shall be locally in excess in the relatively quiet water at the inside of a curve. The River des Peres has good meanders in its lower course, yet it is not an aggrading stream. It has probably ceased to deepen its valley with reference to the adjacent hilltops, which are themselves beginning to cut down, but the valley bottom is likewise approaching base level.

Change in Form of Curves.—The manner in which meanders originate implies a constant change of form. In fact, as the curvature is progressively increased, the tendency to deposit on the concave side becomes progressively greater. This implies a corresponding acceleration of erosion of the outer bank. Mathematically expressed, the radii of meanders tend constantly to decrease. The ultimate effect of this tendency is to produce closed curves, formed by the stream's intersecting itself (Figs. 4 and 5). The completed circle or closed curve is then abandoned, and the stream is temporarily straighter than before. In this way cut-off or ox-bow lakes are formed, like Horseshoe and Pittsburg Lakes on the Mississippi flood-plain, and Creve Coeur Lake on the Missouri flood-plain. For a time such abandoned arcs are in free communication with the new channel, but as the muddy water of the stream enters the ends of the abandoned curve its motion is lost and some of its load drops. Thus a dam is soon built at each end, and the remnant of the old channel becomes a closed basin.

Change in Position of Curves.—If any one meander curve be mapped in successive years, it will be seen to change its position as well as its form. Each meander is found to be moving down stream (Fig. 5). This is because a stream in flowing transversely across its flood-plain cuts more rapidly on that bank which is on the down-valley side. This down-stream migration of meanders is important. The river of each meander swings only toward its outside curve; therefore so long as a meander holds its position, there can be no return of the stream toward the other bluff except by a cut-off. But as a curve which is cutting toward the right moved forward, that is, down stream, a curve which is cutting toward the left occupies its place and the stream begins to swing toward the other bluff without a cut-off. An alternation is thus brought about which is very important in giving to flood-plains their characteristic form.

Planation.—The work done by a stream in the process of meandering is both destructional and constructional. Its destructional work is done against the outer bank of each curve. This bank may consist of the river's own alluvium, or of the original material in which the valley is cut. In either case the river planes the country to its own level and produces a flat which is co-extensive with the area over which the stream has meandered. This process is *planation* and is the essential process concerned in making a flat bottom in a valley which is not being aggraded. Even in such a case there is a coating of alluvium, but its thickness is roughly uniform and it is, therefore, not the primary cause of the flat.

The flat bottom is limited by slopes which are commonly steeper than any slopes of the original surface, because made by the cutting of the river at their base. These slopes are the bluffs. Their distinguishing characteristic is their steepness, and their chief significance in the history of the surface lies in the fact that they mark the lateral limits of the stream's meandering and planation. They are, therefore, composed essentially of the material in which the valley is cut. Usually this is not



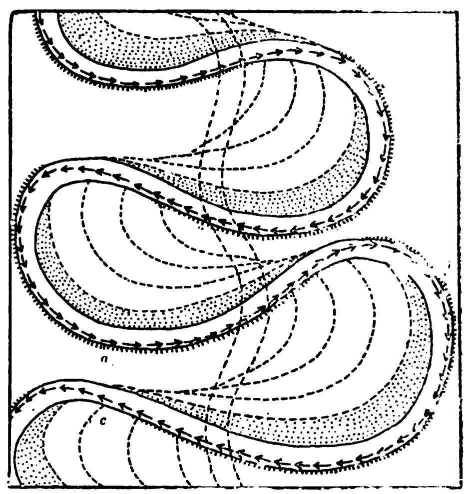


FIG. 4. Diagram illustrating an early stage in the development of meanders. The dotted portion represents the area over which the stream has worked.

FIG. 5. A later stage in the development of meanders. The several curves have not only widened their swing but have moved down stream.
Both from Salisbury's Physiography, p. 187, courtesy of Henry Holt & Co.

alluvium, but where a stream has cut down beneath its flood-plain and formed terraces, bluffs are cut in the older and higher alluvium. In this case those cut in the original country rock may be distinguished as the *outer bluffs*.

Where a stream, meandering on its flat, flows at the foot of its bluffs, it is widening its trough and flood-plain. This is very noticeable at many places on the Mississippi where railroads have been built at the foot of bluffs. Expensive work and frequent repairs are often necessary to prevent the roadbed from being washed away by the river in its efforts illustrated by the Meramec near Valley Park, Mo., (See Pl. 13, also geo- to widen its valley. The broadening of a flood-plain is particularly well logic map, Pl. 18).

Occasionally in the process of meandering and planation, a stream may skip certain small areas, leaving unconsumed mounds by the change of its course before their planation is complete. This is far more likely to occur when a stream is cutting down its channel rapidly beneath the level of its own flood-plain, a process discussed on page 55. In this way a considerable group of mounds of various sizes was left a few miles northeast of East St. Louis. Some of these have subsequently been modified artificially, and their present forms give little suggestion of their origin. (See p. 63.)

Alluviation.—The constructional work involved in meandering consists largely in the deposit of sediments on the inside of meander curves, the reason for which has already been explained. (See p. 34). The effect of this is to follow up the shifting stream with a deposit (generally sand and gravel) laid in oblique layers (Fig. 6) as high as the surface of the river. The bottom of this deposit is the planation surface made in the stream's meandering. The alluvium therefore constitutes a mere veneer whose surface is approximately parallel to the bed on which it rests.

Alluviation also includes the deposition of material from suspension in flood waters. Since the deposition from suspension is due to loss of agitation, it occurs most abundantly where check is most pronounced. This is just at the point where the stream gets beyond its natural channel, for the contrast between the violent swirl of the flood within the channel, and the conditions over the nearby plain is greater than the contrast within a similar distance at any other place subject to overflow. If the stream is entirely unable to cut down its channel, this extra accumulation on its banks will ultimately cause the flood-plain to slope away from the stream (Fig. 7.). This is very conspicuous on the Lower Mississippi but is not the case near St. Louis. Along streams which, in the long run, are able to cut down their channels, this extra deposit of silt near the banks is washed into the stream between floods and is therefore not cumulative.

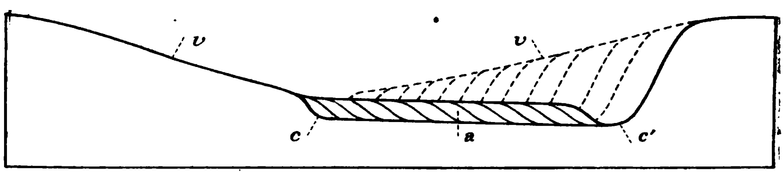


FIG. 6. Making of a flood plain by planation and lateral accretion of alluvium: *v*.—Original valley slopes. *b*.—Bluff being cut away at the base of the stream. The parallel dotted lines show successive position of the bluff as the channel shifted from left to right. *c*.—Original channel. *c*1.—Present channel. *a*.—Alluvium, deposited on the left side of the channel as the latter shifted toward the right. By subsequent shifting to the left the stream will cut a similar bluff on the other side of its valley.

Flood-plain Making.—The making of flood-plains by meandering alone involves two very characteristic processes, planation and deposition within curves. The latter may be distinguished as *lateral accretion* and contrasted with *vertical accretion* which consists in raising the height of flood-plains by layers of mud dropped from suspension in times of overflow. In the building of most flood-plains lateral accretion is far the more important process. Some flood-plains are built entirely without overflow.[1]

In a section through an alluvial plain the amount of accretion due to each of the above methods may be roughly determined by the nature of the material. Most of the sand and gravel has been deposited by lateral accretion and is not due to overflow, though some has been laid down in channels traversing the flood-plain, and used in time of flood only. On the other hand most of the silt which is incorporated in the flood-plain, has been laid down from suspension in times of overflow.

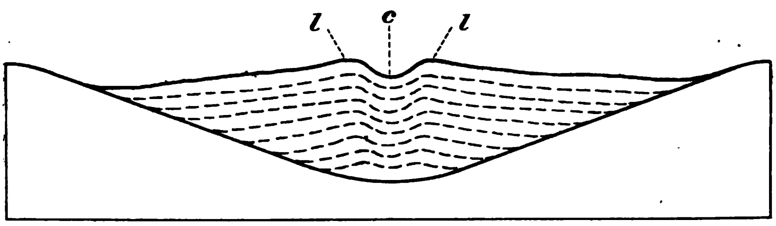


FIG. 7. Building up of flood plain by material deposited by floods. (*Vertical accretion.*) *c.*—Channel. *l.*—Natural levees. Shifting of channel, planation and lateral accretion which commonly accompany this process are not represented in the figure.

Slopes of Flood-plains.—In speaking of planation no account has been taken of the fact that the stream may while shifting laterally, also be cutting its channel lower or may even be aggrading. In the former case, the surface of planation will not be horizontal but will decline toward the stream. This will become clear by assuming that in figure 8 the channel becomes progressively lower while shifting from *C* to *C*[1]. The steepness of the slope toward the present channel will be determined by the relative rates of the lateral shifting and the downward corrasion. Since the thickness of the alluvium laid down is approximately uniform, a flood-plain surface thus formed has about the same slope as that of the planation surface. Even though vertical accretion be large in amount, and though it be much greater near the stream than at a distance, it is generally insufficient to reverse the slope of the floodplain of a cutting stream, because the thicker layer of mud near the stream is in a relatively exposed position, and liable to wash back into the stream. It may, therefore, be stated as a general rule that flood-plains of degrading streams slope toward their streams (Fig. 8). This is true of all flood-plains in the area here described except possibly that of the Mississippi, which has no decided slope toward or from the stream.

Aggrading streams bring to any portion of their channels more material than they can remove, hence the channel itself is built up or aggraded. Habitual overflows result from this cause, and in such overflows sediment is deposited most largely on the immediate banks (See p. 39). The effect of this is a characteristic slope from the stream toward the

[1]The Writer.—Flood-plains produced without floods. Bulletin Amer. Geol. Soc., Vol. XXXVIII, p. 89, Feb., 1906.

bluffs. This is nowhere better illustrated than on the flood-plain of the lower Mississippi, where the slope from the river's bank is frequently 7 feet in the first mile, and sometimes as much as 20 feet in all.

It is theoretically possible, of course, that a stream should be neither aggrading nor degrading, thus giving to its flood-plain no lateral slope. Or such an absence of slope might indicate that the influence of a very slight degradation of the channel is about balanced by the greater deposition of mud near the river. This seems to be approximately the condition of the Mississippi and its flood-plain opposite St. Louis.

Alluvial Terraces.—Within the area here described, alluvial terraces are not extensively developed though even small ones are important in the interpretation of the physiographic history.

Since an alluvial terrace is essentially only an old flood-plain which can no longer be reached by overflow, it will be seen that it may develop in the normal course of a stream's down-cutting. For example, a stream which has shifted eastward and then again westward while corrading its channel downward, may easily find, before reaching its original position, that the remnant of its old floodplain on the west is too high to be flooded (Fig. 8). In repeated shiftings it may leave any number of floodplain remnants at different heights. This condition calls for no sudden changes or even varying rates of activity.

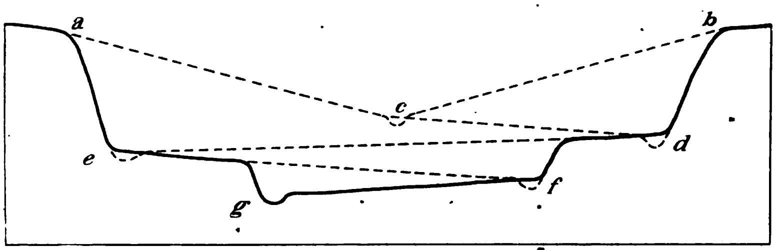


FIG. 8. Making of alluvial terraces by normal downward corrasion and meandering. *c, d, e, f, g*—Successive positions of the stream channel. (Compare Fig. 6). The present surface is indicated by the full line. Former surfaces destroyed by erosion are shown by dotted lines. *a c d*, original valley; *c d*, first flood-plain; *d e*, second flood-plain partly preserved as terrace; *e f*, third floor plain preserved as terrace; *f g*, present flood-plain.

The finest and largest terraces are, however, generally due to some variation in the stream's circumstances which gives a definite period of down-cutting, following a period of little or no down-cutting. This change may come about by giving the stream additional power, (perhaps by increased fall or increase of volume) or it may result from a decrease of load. The importance of even small terraces along the Mississippi is due to their connection with this latter principle, for such a decrease of load must have occurred when the ice cap left the headwaters of the Mississippi. Alluvium deposited while the ice cap was on, and the stream was loaded, remains in fine terraces farther north, but it is sparsely represented in this area.

GRADING.

By the profile of a stream is meant the form of its bed considered with reference to its slope only. It therefore ignores the stream's lateral turns or horizontal plan. It may therefore be represented as a curve in a vertical plane (Fig. 9). Corrasion and deposition tend to give continuity to this curve, that is, to do away with repeated changes from gentle slope to steep and the reverse. The process by which this is done is called grading. The study of this area does not call for a critical discussion of the process. A little reflection will show that the down-cutting which occurs on the originally steeper slopes is more in their upper parts than in the lower, and therefore reduces their slope; also that the deposition on the flatter slopes is concentrated near their upper parts, thus increasing their slope (Fig. 9). The final result is not a *uniform slope* but it is a *continuous slope*, which is concave upward, being steeper near the headwaters. This is because the stream needs a greater slope where it is small and its power is to a large extent used up in friction on the bed. When a stream flowing over strong and weak rocks has produced such a profile, it is said to be graded.

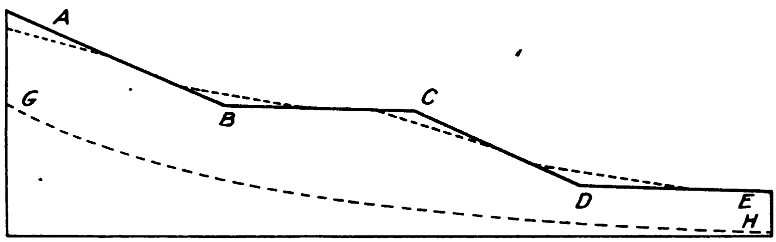


FIG. 9. Grading of a stream channel. The steeper portions, *AB* and *CD* are cut down first at their upper ends, thus decreasing their grade. The flatter portions, *BC* and *DE*, are built up at their upper ends, thus increasing their grade. The entire course tends toward a continuous but not uniform curve similar to *GH*.

Another consideration in grading is the relation of power to load. On the steep slopes the former is in excess; on gentle slopes the latter. The equalizing of slopes as described above tends toward a condition in which the power will everywhere be just sufficient to transport the load, but not to corrade the channel except as the neighboring slopes and hills are simultaneously worn down. It may be shown that these two aspects of grading agree in the main, that is, that the continuous and harmonious slope is reached only when the stream's power has become just equal to its needs for transportation. It follows also that so long as a stream has surplus power it will make a distinction between strong and weak rocks, having its profile steeper on the former than on the latter: but when power and load have been equalized no such distinction appears.

The small streams emerging from the bluffs are in general above grade. Their surplus power is revealed by (1) the steepness of the side slopes of their V-shaped valleys (See p. 36), (2) the steepness of their profiles, especially near the valley heads, and (3) the inequalities of their profiles, many of which show rapids and small cascades. Some of these streams are making conspicuous efforts to equalize their steep slopes in the bluffs with their gentle slopes on the flood-plain. Schoenberger's Creek, for example, is depositing great quantities of sediment at the foot of the bluff in the form of a wide alluvial fan.

Progressive Changes in Topography.

The combined effect of all the erosional processes described above is a progressive change in topography. The nature of these changes is so well known that if the form and materials of the original land form be given, the succession of topographic features can be predicted until the entire area shall have been cut down so near to sea level that running water can have no further effect. Regardless of initial form, this is the fate of all land masses, unless the process is interrupted. Or, if the topographic features at any stage be given, former features may be known and even to a considerable degree the form of the original uneroded surface.

The succession of features of interest in this area is that which begins with a somewhat elevated plain more or less abruptly limited by steep sides, such as are represented by the present bluffs.

BEGINNINGS OF DISSECTION.

The first effect of running water on such a surface is the making of gullies at its edge. These grow headward and send out branches until by many such systems the edge of the area has lost its flatness and consists of hills and ridges. A condition approaching this is still seen both north and south of Caseyville where the plateau on the east is limited by the Mississippi bluff. This is not an accurate and simple illustration of the beginning of dissection at the edge of a plateau, for, as noted elsewhere (p. 20), the present valleys are not being elongated headward in a plateau which is entirely devoid of valleys. The present streams are rather to be considered as deepening the lower courses of shallow valleys already in existence as will be seen later, in the discussion of the history of the present surface (p. 54.). Nevertheless the topography shown at the present time differs little from that of a low plateau edge being dissected for the first time. The largest approximately level tracts are found along a line extending from a point west of Belleville, in a direction east of north toward Troy. Here is a belt generally a mile or more in width which remains nearly flat. Northwest of Troy it broadens to several miles. On the west side, the direct tributaries of the Mississippi and, on the east, those of the Kaskaskia are sending their headwaters into this belt and dissecting its edges.

MATURE DISSECTION.

So long as the dissection of a plain surface is not complete, many hills and divides continue to rise to about the same height, which is approximately that of the original surface (Fig. 10). They have varying widths, and all are being narrowed by the wasting of their sides, but they cannot be much lowered so long as any part of their flat tops remain. The narrowest will first be reduced to points or crests, after which the continued wasting of their sides will lower their crests. Ultimately every ridge must thus begin to cut down. When practically all of the original flat upland has thus disappeared, the country is said to be completely or *maturely* dissected.

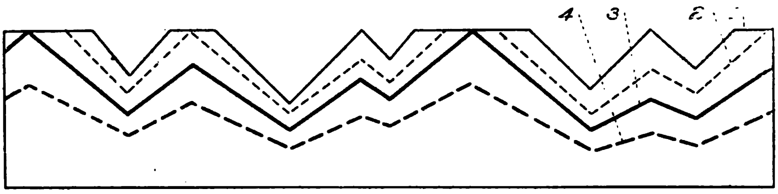


FIG. 10. Diagram illustrating progressive dissection of a plain surface. The stage represented by line *1*, shows flat hilltops of unequal breadth and several which are already reduced to points or crests. In the second stage the points are cut down and the flat tops narrowed, one of them to a point. In the third stage no flat tops remain and dissection is *mature*. In an extended area a number of other hills would be found rising approximately to the level of the original plain surface. In the fourth stage all are approaching base level but there is no longer any uniformity of height.

Most of the uplands of this area are in this condition of mature dissection. The hills and divides have been narrowed to points of ridges, but so many of them still rise to about the same height as to leave no doubt that the level thus marked is essentially that of the former plain.

Since the hilltops have held their own up to the time of mature dissection, while the valleys have been deepening, the relief is greater now than ever before. It is also greater than it will be in the future, for it may be shown that henceforth the hilltops will cut down more rapidly than the valley bottoms. The stage of mature dissection is therefore also the stage of maximum relief. Slopes, power of streams, and load of sediment are therefore also at a maximum. It does not follow that the stage characterized by these maxima should coincide with that at which the streams reach *grade,* but such is approximately true of this region. Graded streams are sometimes called "mature" and that word is therefore sometimes used for one stage with reference to streams and another with reference to the country which they dissect. The confusion thus threatened, can perhaps best be avoided by dropping the use of the word with reference to streams and channels, in which case the word "graded" expresses all that is intended.

WEARING DOWN OF HILLS.

After maturity is passed, the hills lose their uniformity of height, for the crests of the narrower ones not only begin to be lowered sooner, but are cut down faster than the broader ones. With continued erosion toward base level, the relief decreases, and with it the inequalities among hills, until the entire area is but little above sea level. Being "almost a plain" it is then called a *peneplain.*

The Peneplain in This Area.—There is no simple illustration of this stage of erosion in the area here considered, that is no peneplain is now found at the level at which it was made. The geological evidence is however complete that the once nearly flat surface of the upland was produced in this way. The present hilltops and ridgetops which are of nearly uniform height are all that remains in this locality of a well developed but subsequently eroded peneplain. When made, it was but little above sea level. The present deep valleys were, of course, impossible at that time. Whatever streams then existed must have been without cutting power, and meandered widely over the nearly flat land. The making of this peneplain is among the most important events in the history of the present surface. This is described on page 52.

RENEWED UPLIFT.

Cycles.—When an old peneplain is elevated, erosion has renewed power and dissection of the surface is again begun. In many respects this second dissection resembles the first. Both begin with a plane, or nearly plane, surface and end with the same, passing through a stage of mature dissection and maximum relief. The essential repetition of the same processes in similar order has caused the term *cycle* to be applied to the entire round of events from the beginning or erosional work to its close, or sometimes to the *time required* for all. A region may thus pass through any number of cycles, according to the number of times it is uplifted. This region illustrates perfectly the dissection of a low plateau in its second (or later) cycle. Many other cycles may have been completed before the first one of which record is left. The present cycle is loosely called the second, only because the one which ended with the peneplain represented by the present tops is the oldest of which a record is left.

Stream courses of the second cycle.—Unless the land is submerged at the close of the first cycle or the old valleys effaced in some other way, the second cycle in not in all respects like the first. If valleys remain after uplift, their courses need not be again determined by the process of headward elongation. To a certain extent the country will have a "ready made drainage system," and to a certain extent down-cutting will begin over the entire area simultaneously, and the many even-crested divides will have something like an even start in the process of down-cutting. The consequent cutting down of these divides includes some features calling for explanation.

Erosion of divides in second cycle.—There is reason to think (See p. 55) that the uplift of the old St. Louis peneplain raised it to an elevation about 50 feet above the level of the even-topped ridges which now constitute the upland; or would have raised it to that height had not erosion been at work while the uplift was in progress. When the present uniformity of height of the divides is considered, it appears that they must have been worn down with a uniformity that is noteworthy in view of the fact that the first great topographic result of stream erosion is the roughening of surfaces by the making of valleys. This diversification is due to the fact that running water works mainly, or at least most conspicuously, by the making of valleys. The wearing down of these divides in the manner supposed must, therefore, have been accomplished without the making of valleys, on their slopes; that is, by the unconcentrated wash of surface waters.

It is common to think of this condition of unconcentrated wash as a very unstable one, liable at any time to give way to that of valley-cutting at any place where chance furnishes a slight excess of water. Valley cutting, once begun, generally proceeds with cumulative power and certainty, so that a condition of unconcentrated wash is apt to be regarded as implying a neat balance, preserved only by the rarest chance. It may be shown, however, that *within limits* and sometimes very broad limits, this condition tends to perpetuate itself; that the equilibrium is automatically restored when lost, and that this may continue for an indefinite time, and during the accomplishment of an indefinite amount of erosion. This condition results from the principle now to be considered.

It is a familiar principle that when two streams unite, their combined waters are less impeded by friction than before and they are therefore able to transport their combined load with greater ease or to transport a larger load or, if no additional load be furnished, the enlarged stream may corrade its channel. Streams which send out distributaries in the process of delta-making lose much power by such subdivision, and must deposit far more than the mere excess of load which the stream had in its undivided condition. A stream with large cutting power may thus be divided and subdivided until each one of the resulting distributaries is unable to carry its proportional part of the original load.

In considering the headwaters of a stream which gathers its waters from surface run-off, the opposite is true. At a point near its source it may have power far in excess of that needed to carry its sediments and so corrade its channel vigorously. Traced headward, however, the stream is found to consist of many smaller ones. A degree of subdivision will ultimately be found in which the individual streamlets are so impeded by friction that the available power is not sufficient to transport the load found along its course. The word *rill* is suitably used to denote streamlets of this kind.

Streams in the condition here referred to are generally called *overloaded.* It is their habit to run in shallow channels often subdividing and shifting. Sand bars are formed now at one place, now at another, and are a further means of shifting the channel. In the case of overloaded rills, the channel is often obliterated between one rain and the next, but their inability to cut channels is ultimately dependent on their overloaded condition rather than on their periodic nature. Streams in this condition, like all other streams, seek out the lowest places but these instead of being still further deepened are promptly filled. The topographic effects of all overloaded run-off (including rill wash) may therefore be contrasted sharply with that of underloaded run-off. The characteristic and universal tendency of the first is to level the surface just as that of the second is to diversify it. Therefore until the run-off reaches a degree of concentration such that the power is sufficient to transport the load offered, the failure to cut valleys is not an exceptional case due to the preservation of exact equality among neighboring rills and ceasing when some slight furrow is found or produced, but is the normal condition, providing for its own continuance by obliterating such inequalities as may be fortuitously started.

It is not to be assumed that running water in this condition cannot cut down the surface over which it runs. Many streams whose channels contain more loose material than the stream can transport are indeed aggrading their channels and filling their valleys. But this is not necessary. The above described habits due to "overloading" do not necessarily imply aggradation. They are dependent solely on the *presence* of more loose material than can be transported. In the case of some streams and most rills, the material both beneath and beside the stream is of such a nature as to furnish an unlimited supply of loose material, and the above mentioned habits are induced, regardless of the fact that more material is being removed from a given point than is brought to it. Rill wash on divides and slopes is probably always an eroding agent.

Where, as in this region in its present cycle, the degradation of an entire area is begun at essentially the same time by a ready-made drainage system, the interstream areas are sub-equal ridges whose tops are not entirely flat, and which are subject to degradation by unconcentrated wash at approximately the same rate. This is believed to be exemplified in the region here considered by a loss of altitude of the old peneplain amounting to about 50 feet. Yet so uniform has been this degradation that the present appearance of the surface is in no way differentiated from that of a maturely dissected peneplain whose ridges maintain their original level. The fuller discussion of the St. Louis peneplain in the light of this principle is reserved for the History of the Present Surface. (See p. 57).

EARLY GEOLOGICAL HISTORY.

DIVISIONS OF HISTORY.

The geological history of this area divides itself naturally into two main parts. The first part is that which antedates the making of the present surface and is therefore purely geological. The second part begins with the oldest events and conditions whose record is preserved in the present topography. It is therefore the physiographic history. The records of the former times are preserved only in the rocks. The older part of this ancient or distinctively geologic history is inferred from rocks which do not outcrop within the area but south and west of it nearer the Ozark highland. This is the history of pre-Carboniferous time. The later part is read in rocks which outcrop within the area. From the most ancient geologic history to the most recent, therefore, the data become more and more direct. That part of the history which antedates the making of the present surface is of very subordinate importance in a physiographic study and is sketched here in a very general way.

THE OZARK PROVINCE.

The St. Louis area lies on the northeastern border of the Ozark region. This region is now elevated above its surroundings and would constitute an island if the sea should rise to a suitable height. Something like these same relations may have existed at various time throughout geologic time. The Ozark region has varied in altitude both with reference to the sea level and to the surrounding country, so that sometimes in the course of geologic history the whole region has been submerged, at other times it has all been land and at still others the Ozark land has been an island. The history of the St. Louis region is, therefore, involved in that of the Ozarks. In so far, however, as the history of the former must be inferred from that of the latter, it should be borne in mind that the St. Louis area lies well out on the flank of the Ozark uplift, and was, therefore, submerged and receiving sediments a relatively large part of the time.

PRE-CARBONIFEROUS TIME.

This area was probably covered by the sea during at least a part of the Proterozoic era though all the deposits then made may have been eroded away during the long succeeding time when the whole area was land. This land period seems to have lasted throughout the latter part of the Proterozoic and through the first half at least of the Cambrian.

During the latter part of the Cambrian period and throughout the Ordovician, the region was under the sea most of the time. For most of this time this sea was wide-spread, probably in all directions from this place. Under such conditions little or no detritus from the land reached this place, and the sediments were mainly limestones. Between 2,000 and 3,000 feet of sediments were thus accumulated, all of which are deeply buried beneath this area but come to the surface south and west of it. (Pl. 1, A. and B.)

At intervals throughout this time, crustal movements made the water shallower or brought the shoreline nearer or did both, or the slope of the land may have been steepened, thus enabling the stream to carry coarser sediment. At such times sands were deposited which now appear as sandstone formations. Some of these several hundred feet thick, are interbedded with the limestones. Four of these sandstone-making times are more noteworthy than the rest, the first being in the latter part of the Cambrian period and the last in the St. Peters epoch in the latter part of the Ordovician.

In the St. Peters epoch there was laid down the remarkable sandstone (See p. 66) which is now dug out for glass manufacture at Pacific and Crystal City, and from which salt water is derived by deep wells in St. Louis. The grains of this sand are more rounded than those of any known sands except dune sands. It is therefore inferred that they were blown about on the beach until thoroughly rounded and were then submerged. This implies that the area occupied by the St. Peters sandstone was land at the beginning of the epoch and that the border of the sea migrated across it during the epoch.

Brief land intervals like the one here mentioned probably occurred at other times during the Cambrian and Ordovician periods. During one such, which followed the St. Peters (locally at least) the strata of that age were considerably deformed. At Pacific they may be seen tilted at an angle of about 15°, and unconformably overlain by horizontal limestones. (Pl. 16, A.)

The St. Peters epoch was succeeded by another long time of limestone making in the Stones River and Trenton epochs, when the seas were again free from land-derived sediment. Then an uplifting of the land enabled the streams to carry to the sea great quantities of mud, making the Maquoketa and other shales which make the upper part of the Ordovician system and which may be seen south of St. Louis near Kimmswick.

Probably this area was land throughout the Silurian and Devonian periods. If any sediments were laid down here during that time they were washed away or cannot be distinguished from those above and below. The land of that time could not however have risen high or the shales made late in the Ordovician would have been eroded away.

THE MISSISSIPPIAN PERIOD.

At the beginning of the Mississippian period submergence again took place. The first effect of the invading sea was to work over and stratify the decomposed mantle rock of the former land. As the land was not entirely flat, the incoming sea was not of uniform depth. In its clearer parts, a little limestone (the Glenn Park) was laid down, while in places of greater agitation a little sandstone (the Bushberg) was deposited. These were soon covered by a considerable deposit of mud, much of which has a reddish color (the Fern Glenn shales.) It doubtless represents the greater part of the former soil which was thoroughly decomposed by long exposure and may have been reddened by the complete oxidation of its iron compounds.

Further deepening and consequent removal of the shore to a greater distance from this place, again allowed the calcareous remains of marine animals to accumulate without much admixture of mud. Under these conditions were made the hundreds of feet of limestone, composing most of the Mississippian system and embracing the Osage, Spergen and St. Louis formations.

During the making of much if not all of this limestone, the sea was shallow. Some of the St. Louis beds are beautifully ripple-marked and much of the Spergen and of the St. Louis is cross-bedded. A slight interruption of these relations after the Osage resulted in a conspicuous admixture of mud along with the limestone. The deposits of that epoch are the Warsaw shales.

Toward the close of the Mississippian the sediment became sandy probably indicating further shallowing, but more especially an approach of the shoreline by the rising of the Ozark land. The deposit of this time is the Chester sandstone which underlies most of the area east of the Mississippi.

Following the Chester, the whole area became dry land again and continued so while the recently made Chester and the older limestones were considerably eroded. Slight crustal movements or warpings also occurred before the land was again submerged, so that the Mississippian strata have more of a northeasterly dip than the overlying beds. (Pl. 1, B).

THE PENNSYLVANIAN PERIOD.

The next great sinking of the land inaugurated the great coal making period, the Upper Carboniferous or Pennsylvanian. Swamps existed simultaneously over very large areas so that a considerable part of central and eastern United States was repeatedly subjected to such conditions during this period. At such times the peat accumulated which afterward became coal. Dry land conditions existed at various times and places. At intervals also the land was submerged beneath the sea so that marine shales, sandstones and limestones are interbedded with the seams of coal. Several coals were deposited in this area, but only one (the Belleville seam) is thick enough for profitable mining.

A—Unconformity at Pacific, Missouri. The white rock is the St. Peters Sandstone, which is here dug out for glass sand. Much of the artesian water in and around St. Louis is derived from this same stratum.

B—Crossbedding in Spergen limestone, Meramec Highlands, Missouri.

In addition to the coal making of this period, another important process was the change effected in beds of clay which were covered by swamp waters. Such waters are charged with organic acids whose effect is to leach out of the clays such constitutents as make them readily fusible. In this way *fireclays* were produced. A bed of such clay underlies large areas within the city of St. Louis, as well as west and north of it. Its thickness varies from 2 to 12 feet.

At the close of the Carboniferous period the land rose and it is not known that this area was ever again submerged. The uplift was accompanied by much deformation, and it is not known to what altitude the land was lifted. Of the many minor events which may have transpired in the long time between the Carboniferous and a relatively recent geological epoch, no record is preserved in this area. Only the grand result of all is known, that is the wearing down of the land almost or quite to base level.

THE MAKING OF THE PRESENT SURFACE.

THE PENEPLAIN.

The reduction of the uplifted post-Carboniferous surface to a peneplain of very faint relief was the first step in the making of the present surface. This plain is now preserved only on the hill-tops and ridge-tops, but the fact that they are remnants of a former plain is recognized by the uniformity of their altitudes, so that the horizon as viewed from any one of them is almost perfectly flat. The area here described is only a very small part of a wide expanse showing this same general feature.

The time at which this peneplain was completed is not known. It may have been perfected repeatedly and each time uplifted to be worn down again. A peneplain is a valuable record of a relatively recent event but it is in the nature of such records that each one destroys its predecessors more or less completely.

In many parts of the United States certain remnants of peneplains are believed to date back to the Cretaceous period. At many places there are remnants of two peneplains; an older (higher) partially destroyed, and a newer (lower) but partially completed. The older in some cases is believed to have been completed in Cretaceous, and the newer in Tertiary time. They may on the one hand be separated in altitude by many hundreds of feet, and on the other hand they may approach indefinitely near to each other. Where the latter is the case, the older peneplain must have maintained its position near sea level, and therefore its form, during the making of the newer peneplain elsewhere. As for the St. Louis region it can only be said that the area seems to have been a peneplain and probably but little above sea level, as late as the Pliocene (late Tertiary) period. How long it had been in that condition is not known. If a peneplain covered this same area in Cretaceous time, it was either preserved in form and altitude until the late Tertiary, or completely destroyed in the making of its successor.

THE LAFAYETTE.

Probably in Pliocene (late Tertiary) time, the peneplain, or at least a part of it, was covered by a deposit of gravel known as Lafayette. The identification of the patches of gravel remaining in this area with the Lafayette is based mainly on their striking physical characteristics (See p. 9). Not only is there no observation inconsistent with this identification but the topographic relations of the gravels strongly support this assumption. It is fair to assume that the gravel, which now remains in patches only, was once more or less continuous over the area.

The exact origin of these gravels and the manner of their deposition is not certain. Where carefully studied nearer the edge of the continent they are believed by some[1] to be a marine deposit while others believe them to have been made by rivers.[2] The study of the few patches remaining near St. Louis is not a sufficient basis on which to build an argument. So far as the relations here shown are concerned, there is no reason to assume that this gravel was laid down in the sea.

It may be assumed that, in the nearly perfect condition of the peneplain, the streams which made it wandered over its surface somewhat aimlessly, transporting little or no load except what they carried in solution. The mantle rock must have been thoroughly decomposed, containing no stones except such as offer extreme resistance to weathering, for example quartz, chert, jasper, and quartzite. A slight crustal movement, giving additional fall to the rivers, would enable them to carry away the old soil, bearing its finer parts in suspension to the sea, but laying down the gravels in alluvial plains wherever the fall of the streams had not been sufficiently steepened to admit of their being carried forward. The shifting, meandering, and sometimes branching and braiding of streams thus impeded, are sufficient to cover a nearly flat area with a continuous sheet of sands and gravels. Such a condition would account for the Lafayette gravels of this area.

These gravels may also be assumed to be the normal alluvium of the streams during the time when the peneplain was being made. It may then be thought of as beginning to accumulate as soon as the valleys were old enough to have flood-plains. As these valley bottoms became broader, the gravel areas would be increased and as streams meandered repeatedly over their flood-plains, at the same time slowly cutting down to easier grades and lower levels, the alluvium must have been worked over many times, until its less resistant pebbles were worn away and its finer constitutents for the most part carried to the sea. It is probably necessary to assume with this hypothesis, some temporary increase of stream power in order to provide for the washing out of the finer materials, mud, etc., which must originally have been associated with that which now remains.

At least one observation is distinctly adverse to the supposition that the Lafayette of this vicinity was formed in the sea. There is, about two miles southwest of Pacific Junction (32 miles southwest of St. Louis) a large deposit of these gravels constituting a terrace along the Meramec river. This deposit is less than 500 feet above the sea, while the remnant northwest of Glencoe is at an altitude of over 750 feet. The latter deposit is northeast of the former, the general slope of the old but unde-

[1] McGee, W. J., The Lafayette Formation, Twelfth Annual Report, U. S. Geol. Sur., Part 1, pp. 349-521.

[2] An explanation of the way in which this may have been done is found in Chamberlin and Salisbury's Geology, Vol. III, p. 305.

formed peneplain being toward the northeast. The deposit near Pacific is therefore, about 300 feet below the level of the old peneplain in that vicinity. It cannot be assumed that these two patches are parts of the same thin sheet deposited on a shallow sea bottom, nor is it feasible to assume that the lower deposit represents a second invasion of the sea after the Meramec Valley was made. If both are stream deposits they might have been made at the same time in valleys of different elevation but this would involve a complication of conditions which need not be assumed. No inconsistency is found in assuming that the deposit near Pacific was made later than that which is represented by the high level remnants and that its material was derived from the sheet laid down on the peneplain. This deposit near Pacific is evidently alluvial, and it is significant as showing what streams can do in the making of such a formation. The question must necessarily arise—if some such deposits are stream-laid, why not all?

If the Lafayette was laid down by streams on a peneplain in the manner described above, its constituent stones were brought from some region which at that time drained toward this place. The location of that region is in some doubt. It must be determined mainly by matching the pebbles of the new formation with the bed rocks elsewhere. Certain pebbles of the Lafayette, notably some quartzites and jaspers, are not matched by any known formations nearer than the Lake Superior region. Since such pebbles are by no means scarce, and some of them weigh more than 100 pounds, their transportation for so great a distance would be remakable. And difficulty involved in this question is independent of the exact manner in which those gravels were deposited.

Uplift and Valley Cutting.

The deposition of the Lafayette was followed by uplift which made the cutting of valleys possible. The valleys then made were probably in the main the ancestors of the present ones. This is truer for that part of the area which lies in Missouri than for that lying in Illinois, whose subsequent glaciation was probably more important topographically. In the main, however, the larger valleys cut at this time have probably never since been entirely filled, while the smaller ones, if partly or wholly filled, have to a considerable extent been re-excavated.

The valleys which were developed after the post-Lafayette uplift are only remotely related to those of the streams which produced the former peneplain. If the Lafayette be assumed to be a marine deposit all pre-existing valleys were, of course, destroyed. If these gravels were laid down by rivers, the deposition of such a sheet was accompanied by such a shifting or wandering of the streams that only the most general resemblance to their former course was left. At the same time tributaries must have become fewer and shorter at their heads because of the porous nature of the surface formation. To whatever extent the streams which made the peneplain may have been adjusted to the character and structure of the underlying rocks, such adjustment may have been lost at this time. The drainage was therefore virtually superimposed on the Lafayette formation.

THE MISSISSIPPI TROUGH.

During the perfection of the peneplain and the deposition of the Lafayette, the Mississippi, like other streams, could not have been more than a very few feet below the general level of the region. At this time it doubtless had at this place a much more meandering course than it now has north of Cairo. These meanders necessarily remained after the uplift and during the renewed cutting. Instead, however, of continuing to wander on a flood-plain, the river by reason of its down-cutting soon came to be shut in by steep bluffs. These bluffs followed the curves of each meander, and faced each other at a distance but little greater than the width of the stream instead of being separated as they now are by a distance several times as great as the diameter of the meander curves. In this condition meanders are said to be *entrenched*. After entrenchment the lateral corrasion or planation by the Mississippi proceeded at a much slower pace. Gradually, however, after the rejuvenated stream had cut its channel down to grade, a new flood-plain was developed at the lower level. The areas within the several ox-bows were slowly narrowed and some of them isolated by cut-offs (See p. 37). By further meandering and planation the bluffs were pushed backward still further, and the isolated remnants reduced in size. In this way mounds were made which were in form and topographic history the exact prototypes of those younger hillocks which now surround Monks Mound and like Monks Mound itself except for its artificial changes.

SMALLER VALLEYS.

The excavation of the Mississippi trough made it possible for the Missouri and Meramec to cut corresponding troughs. The tributaries of these larger valleys which remained on the gravel-covered peneplain were then deepened, and new ones sent out. The earlier limit of the time of this dissection is fixed by the deposition of the Lafayette gravel which was laid down on a nearly flat surface. The later limit is fixed by the deposition of the loess (an incident of the glacial history) which to some extent filled the smaller valleys and stopped their growth. If the loess were now removed they would appear in essentially the same form which they attained in the interval between the Lafayette and the glacial invasion. The surface was then quite as maturely dissected as at present, and probably a little more so.

THE MAKING OF SINKS AND CAVES.

UNFAVORABLE CONDITIONS BEFORE UPLIFT.

It is not probable that the making of existing caves was to any considerable degree started before the uplift and dissection which followed the Lafayette. They could not have been made during the base-leveling process, for caves made then would have disappeared in the downcutting.

Solution of rocks proceeds most rapidly where the atmosphere has access and therefore above the level of the ground water. While the peneplain was close to sea level, the level of ground water was but a few feet from its surface. The horizon in which caves are now found was then below the level of ground water and subject to cementation rather than to solution. It is true that solution takes place locally even under such conditions, but its amount is probably quite inadequate to make large caves. It would indeed be favored by the fact that surface waters in percolating would take with them but little material in solution because they need traverse only a thin zone of thoroughly decomposed rock. Even if, in addition to this fact, abundant vegetation and a correspondingly large supply of carbon dioxide to the ground water be assumed, thus making the water a stronger solvent for limestone, it is not probable that the aggregate of conditions at that time could have been favorable to cave making.

A second condition requisite to rapid solution is a rapid circulation of the ground water. Under a peneplain this is characteristically sluggish as is the movement of the surface waters.

A third and large factor in cave-making in this region is mechanical wear. The cherts derived from the dissolved limestone, form sheets of gravel in the cave streams (See p. 18) so that their downcutting does not differ materially from that of surface streams. This is inconceivable below the level of ground water.

CAVE-MAKING FAVORED BY UPLIFT.

The chief time of cave-making was probably intermediate between the uplift of the peneplain and its complete dissection. The conditions were peculiarly favorable after the larger streams had become incised and before the tributary valleys were well developed. These favorable conditions are:

(a) Very soluble limestones.

(b) A depressed ground water level near the gorges of the large streams, thus giving a thick zone of weathering in which caves could start.

(c) An upland relatively free from valleys and covered by highly permeable gravel, and therefore little subject to surface wash and favoring percolation and sub-surface drainage.

In harmony with these conditions it is seen that the greatest development of caves and sinks is near the deeper valleys (see geologic map, Pl. 18). In one way the large amount of percolation due to condition (c) above, is not especially favorable to the beginning of caves by solution, for it raises the level of ground water, thereby decreasing the thickness of the zone of weathering. It is very favorable, however, to the enlargement of caves by mechanical wear for it practically transfers to the sub-surface a large part (sometimes all) of the energy which would otherwise be spent on the surface, that is it brings to cave-making the energy which is elsewhere used in valley-making. It is also true that abundant percolation implies vigorous circulation of ground water, a very important factor in cave-making.

CONTINUED ENLARGEMENT OF CAVES.

The enlargement of caves and passages still continues, though in some cases the rate has probably fallen off. The development of a system of surface valleys and the destruction of the gravel covering have increased the percentage of run-off at the expense of percolation. In some areas, however, the development of sinks has forestalled that of the valleys, which will continue to be impossible for a long time to come. In such places, as for example between Hickman Creek and Falling Spring, the enlargement of subterranean passages (possibly actual caverns) is probably more rapid at present than at any former time. The progressive enlargement of these passages furnishes an increasing stock of chert gravel to aid in their further corrasion. In the vicinities of both the caves examined (See p. 20), there is the same lack of surface valleys, and the same probability exists that these caves are being enlarged more rapidly than at any former time.

DEGRADATION OF THE PENEPLAIN.

The horizon of the old peneplain is inferred to be approximately that of the present hilltops. It is indeed from the uniformity of altitude of these hilltops that the existence of a peneplain is inferred.

As already suggested (See p. 47) there is a reason to think that the actual level of the peneplain was perhaps as much as 50 feet above the present hilltops. This is inferred from the presence of Lafayette gravels on exceptionally high hills, and the general absence of such gravels at lower levels. Whatever theory may be accepted as to the origin of these gravels, it is impossible that they should have been deposited on high points in preference to lower surroundings. The upper surface of the gravel deposit must had been approximately flat.

The present topographic situation of the Lafayette may be explained in three ways. (1) The pre-Lafayette surface may have been just that now represented by the hilltops (assuming the loess and the gravels themselves to be removed), that is, the present exceptionally high points may have existed then as now, all being buried by gravel to a depth extending about 20 to 30 feet above the highest hilltops. This would imply a sheet of gravel 70 or 80 feet thick. Erosion after uplift may then have entirely carried away the gravel where thickest, denuding the country just to the level of the floor on which the gravel was laid, but leaving it on the exceptionally high points. A study of the behavior of gravel under erosion does not favor this hypothesis. (2) The pre-Lafayette peneplain may have been at the level of these exceptional heights where the gravel is now preserved. Then an elevation of about 50 feet may have been succeeded by a new peneplain on which the hills now bearing the gravels stood as monadnocks. (3) The gravel-covered peneplain may have been trenched by its ready-made drainage system, the divides being in general so narrow that no flat ground remained. Partly during this process and partly following as the result of it, the interstream areas were lowered by unconcentrated rain wash, (See p. 46). At the few places where the interstream areas were wide enough to be flat-topped such erosion would be inefficient. This condition might be expected to exist along the divide between the Mississippi and Missouri systems where the gravel-topped elevations are now found. This assumption is open to fewer objections than either of the others.

Glacial History.

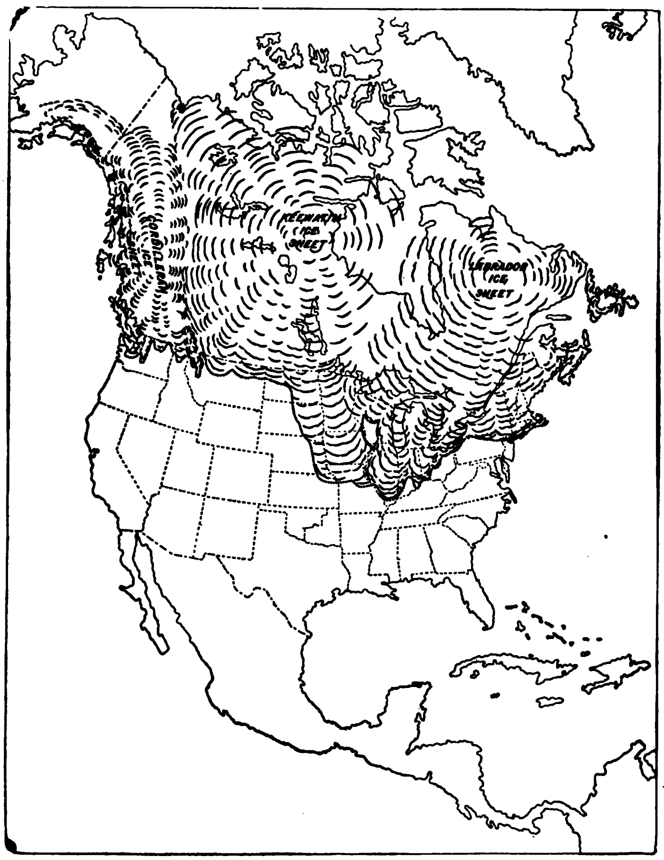
The events of the Pleistocene period caused great temporary changes in the features of this area. They have also left some more permanent changes in the details of the surface. On the whole, however, the greatest change was in the material of the surface rather than its topography.

In this period the ice spread southward over North America, passing in general a little beyond the Missouri river and stopping a little short of the Ohio. (Pl. 17). The extreme limits were not reached at the same time throughout the entire extent of its border. Excess in the rate of advance over that of marginal melting, alternated with an excess of melting. In the former case the edge of the ice moved southward and in the latter it retreated. At least five such alterations are recorded in the deposits. There were perhaps hundreds of smaller advances and retreats, but in the intervals between these five great advances the ice cap probably failed to reach the United States and may have disappeared from the continent. Climatic conditions not unlike these of the present time existed in some and perhaps all of these inter-glacial epochs. Three of these glacial epochs have left definite records within the area here described.

THE KANSAN GLACIAL EPOCH.

The first glacial event known to have affected this region was the ice invasion of the so-called Kansan epoch. The ice at this time came from the west-northwest, and is not known to have crossed the Mississippi, though it made deposits near its banks on the Missouri side (See p. 9). It is not certain that the deposits here were made directly by the ice. There is a suggestion of stratification which may indicate that the material came to its present position by the agency of water while the ice itself did not reach quite to this point. The supposed Kansan drift contains so large an admixture of pebbles resembling those of the Lafayette as to suggest that considerable remnants of that formation still remained when the ice of this epoch moved into this area. So little of this Kansan drift is found, that it is not known or believed to affect the topography to any significant degree.

The chief significance of the Kansan drift lies in its position in the Mississippi trough not more than 30 feet above the present floodplain. The river, therefore, followed its present course and its trough had essentially its present depth at that time. When it is remembered that this trough is still being deepened (See p. 30), it is apparent that the gradient and cutting power of the Mississippi could not have been appreciably greater than at the present at any time since the present course was adopted. Had the continent been for any length of time appreciably elevated above its present level in such a manner as to give the



Map of area covered by the North American ice sheet of the glacial epoch at its maximum extension, showing the approximate southern limit of glaciation, the three main centers of ice accumulation, and the driftless area within the border of the glaciated region. (*Courtesy of U. S. Geological Survey.*)

river additional fall, the bottom of the trough would speedily have been cut so low as to be beyond the reach of scour under present conditions. It is true that the deepest part of the rock trough opposite St. Louis is not beneath the present channel, but the difference is not great enough to warrant the belief that it was cut during an epoch of remarkable continental uplift. The Kansan ice epoch was followed by a long interglacial epoch but of this there is no clear record in this area.

THE ILLINOIS GLACIAL EPOCH.

The second ice invasion of this area came from the northeast. The time of this event is known as the Illinois glacial epoch. The glacier deposited a considerable amount of drift and probably did much to fill the valleys which were already cut in the east bluff of the Mississippi, but this drift is so deeply covered with loess that the topographic effect of its deposition is but vaguely known. This ice sheet crossed the river and left drift at various places in and around St. Louis (See p. 8). Its temporary effect on the Mississippi trough must have been considerable, but it has left no definite record.

THE IOWAN GLACIAL EPOCH.

The Loess.—In the next or Iowan epoch of glaciation the ice itself did not reach this area by more than 100 miles. The events of this time, however, have left a far greater effect on its surface than those of any other ice epoch. This effect is seen in the mantle of loess (See p. 6) which covers the area with the exception of the great valleys.

This deposit is found mainly to the south of the Iowan drift sheet, its thickness diminishing with distance from that sheet. Along the great southward flowing rivers, however, and especially on their east bluffs, its great thickness, sometimes scores of feet, continues for hundreds of miles beyond the Iowan drift. It thins rapidly with increasing distance from these streams until, at a distance of a few miles it is rarely more than 10 feet thick and oftener less than more.

Origin.—The origin and mode of accumulation of the loess are inferred from its constitution and distribution. The freshness of its particles, which are in large part identical with the minerals and rocks of the glacial drift, indicate that it was reduced to its present fineness by mechanical grinding, rather than by decomposition. Its association with and relations to the glacial drift point to the fact that this grinding was done by the ice, and especially by that of the Iowan epoch. Its association with the great streams which flowed away from the ice cap indicate that they were the primary agents of its distribution. Its presence on hills and bluffs regardless of height leaves no doubt that it was transported by wind as well as water, while the greater thickness on the east bluffs of rivers points to the prevalence of westerly winds and suggests that the flood-plains of these streams were the source from which the winds gathered the material.

Following the inferences thus drawn, a picture of the conditions at that time may be reconstructed somewhat as follows:[1] The streams which flowed away from the Iowan ice sheet were heavily charged with silt due to mechanical grinding by the ice. This fact leads deductively to the conclusion, supported by other observations, that the rivers aggraded their channels. In doing this they not only made wide flood-plains, but were subject to great floods. In times of flood, the silt was spread out on the floodplains, and in times of drought it was picked up and carried by the winds over the uplands. Naturally it settled in the greatest quantity where the atmosphere was most heavily charged, that is near the great flood-plains, especially on their east bluffs. A similar process is now going on at the same places, but the amount of dust now carried is too small to accumulate as a distinctive deposit, and it is not improbable that more is now being removed from the bluffs than added to them. Small mollusks which lived on the land and in pools were often covered by the drifting dust and their shells were thus incorporated in the loess. Analogous remains indicate the existence of vegetation at that time.

The farther the loess was carried by winds, the finer its texture, because the large particles settled first. It is on this account that the loess is more clayey at a distance from the great streams. The sheet of this character which stretches as far east as Cincinnati is locally known as the "white clay" though the word "white" is somewhat misleading. The "brown clay" of the states farther south has similar relations to the more typical loess, sometimes called "bluff loess" or simply "bluff."

Effect on Topography.—It is not probable that the accumulation of loess ever completely obliterated the minor valleys, except in the immediate vicinity of the Mississippi and mainly along its eastern bluff. It now mantles the surface somewhat equally, so that, roughly speaking, there is beneath each valley in the loess, a valley in the underlying formation. Previous, therefore, to the accumulation of the loess, the topography was not very unlike the present. It is this fact which makes it practically certain that the old drainage system was not destroyed. Had that been destroyed and a new one superimposed, there would not now be any such agreement between the valleys in the loess and those in the underlying formation. Had the loess of the uplands been deposited by water, its inequality of thickness on hilltop and in valley bottom might well be expected to be very great. In fact it could not well be assumed that the former would receive any significant deposits until the latter were filled. Something like the same would be true, had it drifted like snow or dune sand. In that case also there would have accumulated hills like dunes, more or less unrelated to pre-existing hills and composed entirely of loess.

Even though the mode of accumulation was, as here supposed, mainly by settling from suspension from the air, more should have settled in valleys than on hills, partly because the stratum of dust-laden air was thicker over the valleys; partly because on the whole the air was quieter

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1 See Chamberlin, T. C., Supplementary Hypothesis respecting the origin of the loess of the Mississippi Valleys. Journal of Geology, Vol. 5, pp. 795-802, 897.

there. On the whole the accumulation was without striking phenomena. A repetition of the same at this time would involve (intermittently) a notably dusty atmosphere and some inconvenience in housekeeping, but vegetable and animal life would go right on. In the immediate vicinity of the bluffs there would be occasional patches where the accumulation of successive films or laminae would be so rapid as to produce a definite stratification.

On the other hand it is to be remembered that the loess was subject to stream erosion and transportation then as now, and it is fair to assume that the streams were able to do something toward keeping their valleys open by washing the loess back to the Mississippi. Roughly speaking the tendency of the settling dust to obliterate the valleys and the efforts of the streams to maintain them seem to have been somewhat balanced, or at least sufficiently so to leave the loess-covered surface with essentially the same drainage system which existed earlier.

THE WISCONSIN GLACIAL EPOCH.

After the disappearance of the Iowan ice sheet, conditions were probably for a long time very much as at present. When the ice advanced again, it came only so far as north central Iowa and northeastern Illinois. This epoch of ice advance is called the Wisconsin glacial epoch. Its effect on the area here described was temporary and, in the main, limited to the great valleys. The record within the limits of this area is scanty, and this part of its history can best be inferred from the very clear records left in the Mississippi trough north of the Missouri. It is thus known that the Mississippi was overloaded with sand and gravel at the time when the Wisconsin ice sheet lay in its upper basin. It aggraded its valley to a height at least 30 or 40 feet above its present flood-plain and probably more. Remnants of the material thus deposited are still found on the face of the bluffs.

The partial filling of the Mississippi trough necessarily involved the filling of its tributary valleys to the same level. Remnants of alluvium at high levels in the latter are likewise sparingly found. In these cases the material is chiefly loess, but little modified from its original condition by transportation and redeposition. Even now these small side streams transport mainly loess and during the Wisconsin ice epoch their alluvium must have been almost wholly of this material. Remnants of terraces thus formed are as much as 80 feet above the river, or 60 feet above the adjacent flood-plain.

POST-GLACIAL EROSION.

The term post-glacial as applied to this area is not a definite one because it signifies a different length of time in different parts of the area. Back from the main valleys it began at the close of the Iowan epoch and with the cessation of loess accumulation, while in those valleys it began with the close of the Wisconsin epoch, and the change of the Mississippi from an overloaded to a cutting stream.

Valley Cutting in the Loess.—The extent to which valleys are believed to have been preserved during the making of the loess cover has already been described. When that cover ceased to thicken (that is when deportation became equal to importation by wind) the normal process of valley deepening began. The exact proportion of their depth due to cutting since that time is necessarily unknown, but in view of the looseness of the material and the practical certainty that most of the present valleys have existed throughout post-glacial time, it is at first surprising that valleys have not, in general, been cut entirely through the loess to the underlying rock. The larger ones have indeed been cut to rock and those which pass from the upland to the flood-plain have generally been cut to rock in their steepest parts. Several causes have combined to retard down-cutting by the smaller streams and to some extent by all. The most important of these is the porosity of the loess. Because of this, percolation is free. It was much readier when the loess was new and is constantly becoming poorer as the surface layer weathers and the clay-like crust becomes thicker and more compact. Because of this percolation, many small valleys contain only intermittent streams whereas on a different material these same streams would be permanent. For the same reason all streams are smaller than they would be in less porous material. The greater accumulation of the loess at the line of the bluffs decreased the grade of streams crossing this line to join the larger stream. This also retarded valley cutting on their headwaters and tributaries.

Most small streams, whether permanent or temporary, are at present sufficiently above grade to cut down their channels more rapidly than the valley sides are wasting. This is shown by the shapes of their valleys whose sides usually show an increasingly steep slope as the axis of the valley is approached (See p. 36).

Re-excavation of the Mississippi Trough.—As noted above, the Mississippi trough was doubtless much aggraded during the Iowan glacial epoch and again deepened during the inter-glacial epoch which followed. No known record of these events survives in the area here discussed. The corresponding valley filling which occurred in the Wisconsin epoch is not however, entirely removed. At the close of that epoch, the Mississippi meandered on an alluvial plain not very different in width from its present flood-plain but from 40 to 60 feet higher. The description of the stream as it must have appeared at the close of the Lafayette epoch (See p. 55) applies also to the post-Wisconsin Mississippi. That it meanderd far more than at present may safely be inferred from its known overloaded condition in the Wisconsin epoch. Similar meandering continued to very recent times and the remnants of ox-bows once parts of the channel are preserved in Horseshoe and Pittsburg lakes.

The meanders of this time were incised just as were those which followed the Lafayette. Some cut-offs were effected after the incision, and within those cut-offs stood remnants of the former flood-plain, at that time a high level terrace. Such remnants were eroded and dissected and the several parts were further narrowed by the meander of the main stream and its tributaries until mounds were produced. Among those was the great natural hill which was subsequently modified by man and is now the partly artificial Monks Mound.

The partly artificial character of Monks Mound is evident from its form (See p. 13). That it is in part a natural feature is seen by its structure. Sand is found neatly inter-stratified with loam at an altitude of about 455 feet, or 35 feet above its base. To this height, at least, the mound is natural and as there is sufficient other evidence that the valley was filled in the Wisconsin epoch to at least that height, the original mound may be regarded as a remnant of the alluvial formation of that time. Its base was probably narrowed artificially by the removal of material which was carried to the top. In this way also the conspicuous abruptness of its slopes was probably produced. No natural stratification has yet been found more than 35 feet above its base and therefore, for aught that is now known, more than half its height may be artificial. There is therefore, no reason at present to deny to Monks Mound the distinction claimed for it of being the largest artificial mound of its kind in the world. The time of its building and the people by whom it was built are unknown.

The many other mounds within a mile or two of Monks Mound had the same origin. Several of the larger ones have been similarly altered artificially (Pl. 6). The low ones of gentle slope and less definite outline are believed to be in their natural forms.

CONDITIONS AFFECTING HABITATION.

The conditions which have made within this area a great center of population are found; (1) in its natural resources, (2) in its transportational facilities and (3) in its history.

NATURAL RESOURCES.

SOILS.

Two types of soil are found, the one formed on the loess, the other on the alluvium, the former therefore covering the entire unland region, the latter the great flood-plains. That part of the United States in which loess forms the basis of the soil is perhaps its most remarkable agricultural region. This is largely due to the physical character of the soil. It is mealy and easily ploughed, and contains no stones. Equally important is its indirect influence on agriculture due to its influence on topography. Slopes too steep to farm are rare. Forests existed originally only along the streams. The uplands of this area produce fair or good yields of all the staple crops of this latitude. Except where market gardening demands intensive culture, the value of all crops per acre of improved land is not so large as in the northern half of Illinois and parts of states adjacent.

The alluvium of the Mississippi flood-plain is fertile in places. This is particularly true near the Illinois bluffs where the wash from the bluffs has mingled a large proportion of loess with the alluvium from other sources. Here too, the flood-plain is free from overflow, hence agriculture flourishes. Portions of the flood-plain are so fertile as to repay cultivation despite the liability to floods. Market gardening flourishes in such localities. At other places it is too sandy, or of a fresh and less fertile silt.

MINERAL RESOURCES.[1]

Coal.—The life of the people in this area is much influenced by certain mineral resources. Prominent among these is coal. The area includes a part of the western border of one of the greatest coal fields of the United States. It is known as the Eastern Interior field and oc-

1A more complete account of the mineral resources of this area is given by the writer in U. S. Geol. Surv. bulletin in press, entitled, Geology and Mineral Resources of the St. Louis area.

cupies a large part of Illinois with portions of western Indiana and Kentucky. The two counties of Illinois here represented are among the chief coal producing counties of the State. In 1905, Madison county ranked third with a production of 3,434,399 tons, while St. Clair county ranked fourth with a production of 3,329,914 tons. Many mines are clustered about Belleville and Collinsville, which places owe much of their population and importance to this industry. The coal is of bituminous grade and is largely used by railroads and factories in the production of steam. It comes from a single seam known as No. 6, or the Belleville seam, which averages about 6 feet in thickness and is commonly reached at a depth of 150 or 160 feet below the uplands around Belleville and Collinsville. At present it is mined entirely by shafts but the same seam comes to the surface in the bluffs south of Collinsville and when the industry was in a more primitive condition much coal was taken out along these outcrops.

A small amount of coal once existed in St. Louis county, Missouri, but a large part has been taken out. That now taken out is incidental to the mining of fire clay. The cessation in coal mining here is due chiefly to the fact that the seams are too thin or irregular to repay working under present conditions. One has a maximum thickness of 1½ feet; another which occasionally reaches a thickness of 4 feet is extremely local. The importance of these small coal seams must not, however, be judged by their total contents which would be almost negligible now even if all remained, but rather by their influence on the early development of St. Louis when the supply was ample for the needs of younger industries and transportation was less easy than at present.

Clays.—A second mineral resource of great importance and forming the basis of an industry which supports a large population, is clay. This is of various kinds and affords material for a great variety of manufactures. Of these the most important is fire clay (See p. 51). A great bed of fire clay varying in thickness from 2 to 12 feet is known as the "Cheltenham seam." It takes its name from the village of Cheltenham, now a part of St. Louis, which lies south of Forest Park (the site of the Louisiana Purchase Exposition). In this district fire clay is mined as coal is elsewhere by means of shafts which vary in depth between 60 and 100 feet. About 20 such mines are now in operation in this district alone.

The manufacture of clay products is carried on in the same locality by some of the leading factories of the world. These not only produce fire clay products such as fire brick, retorts, etc., but great quantities of "glass pot" clay which is sent to glass factories at Belleville, Valley Park, and elsewhere to be used for linings. Other wares, such as building brick, sewer pipe, and terra cotta are manufactured in Cheltenham from less refractory clays and shales brought in from adjacent districts.

The shales of the Coal Measures are mined or quarried in considerable quantities west of St. Louis and used in the manufacture of various bricks, sewer pipe and terra cotta. At Prospect Point, north of St. Louis, they are extensively used, along with the St. Louis limestone, in the manufacture of Portland cement.

The manufacture of common red brick from the loess is likewise carried on to a great extent though this product is to a much larger extent consumed at home and therefore does less to give character to St. Louis and East St. Louis as centers of commerce.

The region here described, and chiefly the very small district known as Cheltenham, produced in 1905, about $5,000,000 worth of clay products or about one-thirtieth of the entire output of the United States.

Building Stone.—Several of the formations described on pages 10 and 11 furnish stone for building and for road material. This is especially true of the St. Louis limestone which is now being quarried at twenty or more places within the city of St. Louis and at as many more within the limits of the area discussed. Different beds of the same formation differ greatly in structural value, hence the products of one quarry are put to a great variety of uses. Much of the stone is used in foundations, some in superstructures, some as curbing, sewer plates, etc. Some of the purest limestone is ground up into "whiting." When all the stone suited to these purposes has been removed there remains a large amount which is valuable for concrete or road material. Each quarry therefore operates a crusher to which goes all the stone not valuable for other purposes. The demand for road material is in fact so great that much stone is now crushed and used for that purpose which at a former time might have been used in building. The product of one large quarry in the bluffs of the Missouri river opposite Bellefontaine is used entirely in the manufacture of Portland cement.

It might at first thought be expected that stone so easily obtained and of such fair quality would be in great demand for superstructures as well as for foundations. This seems never to have been the case. Some large buildings including churches both massive and beautiful are built of this stone, but they are relatively few even in St. Louis. On the one hand the general use of lumber, which until recently has been cheap and has always been easily obtained by river transportation, did much to exclude more durable materials. On the other hand, the abundance of brick clays, including the inexhaustible supplies of loess, has afforded a cheaper substitute for stone. Many large buildings in St. Louis are faced with dimension stone brought from Indiana or elsewhere. A relatively small part of the stone quarried in this vicinity is capable of being cut into blocks for such purposes.

Many of the quarries are in the bluffs of the Mississippi and Missouri rivers where the strata outcrop. Those which are surrounded by level ground are often vertical sided pits from 40 to 80 feet in depth. Abandoned pits of this kind in St. Louis have sometimes been used as public dumping grounds for refuse, to the great detriment of local water wells (See p. 68).

Sand.—The uses of sand are varied. The industries of this area are not a little influenced by its proximity to the great sources of glass sand. This is taken from great quarries or rather banks in the friable St. Peters sandstone at Pacific 32 miles west of St. Louis and at Crystal City which is about the same distance to the south. Its high degree of purity makes it valuable as raw material for various kinds of glass. A very large glass factory located at Belleville and deriving its sand from this formation, is devoted chiefly to the manufacture of beer bottles for St. Louis breweries. Important plate glass works located at Valley Park, Mo., use great quantities of sand from Pacific. The use of coal and fire clay by these same factories illustrates the inter-dependence of various industries, and their relation to the material resources. The relation of bottle works to the great brewing interests of St. Louis is apparent.

An interesting relation of industry to natural resources is seen in the local supply of building sand. It is seen from the description of formations on pages 5 to 11 that there are no sand banks in this vicinity except local deposits in the alluvium. All building sand is therefore derived from the bed of the Mississippi river. It is pumped up through pipes 14 inches in diameter, sometimes from a depth of 40 feet, at a maximum rate of 300 cubic yards per hour. An average of about 5,000 cubic yards per day is thus produced.

Another product having a noteworthy relation to physiographic history is moulding sand. That which is produced in this area is derived almost exclusively from the loess. The contrast between conditions on the east and west sides of the Mississippi river while the loess was making is curiously reflected in the fact that the moulders' sand of this origin all comes from the east side. It is dug out at a number of places from Alton southward to French Village. The so-called "sand" is used in part in local foundries, but much of it is shipped elsewhere. A small quantity of moulders' sand of alluvial origin is known to exist west of the river. This will doubtless be developed and may in the future become important.

WATER RESOURCES.

Public Supplies.—The water used in the great cities along the Mississippi is chiefly from public supplies and is derived from the Mississippi. The hard and muddy waters of that river are rendered perfectly clear, relatively soft and entirely agreeable to the taste by modern methods of treatment. The same processes are not used by all the municipalities, but straining, settling, aëration, filtering and chemical treatment with iron sulphate and quicklime, are all employed in one or more public systems. Thus is the great population supplied with an abundance of wholesome water.

Shallow Wells.—Shallow wells are not adapted to a dense population but several thousand of them are still in use in the more crowded parts of St. Louis. The water from them is often clear and pleasant to the taste. Only chemical and biological examination can show its injurious and dangerous character. Not only does the loess at the surface permit easy percolation of impurities, but the limestone below is honeycombed with passages.[1]

Shallow wells in the rural districts vary greatly according as they derive their water from loess, glacial drift, alluvium or limestone. Wells in the loess of the uplands frequently go to the gravelly portion at its base (See p. 7). Here they obtain a moderate supply of fairly good water though it may have a clayey taste.

On the Illinois side and back a few miles from the bluffs, wells for domestic purposes frequently enter the glacial drift. Water thus derived is less liable to contamination than that from the loess, because of the less permeable character of the drift.

Wells on the Mississippi flood-plain are dug (or more commonly driven) to any one of the many sandy layers in the alluvium. A depth of very few feet is generally sufficient, but many wells go much deeper and pierce two or three or even many such water bearing beds in order to get a water supply. Places where limestone lies near the surface in this region are generally characterized by sink holes, and here surface wells are at a great disadvantage. There is, first, a great uncertainty as to the depth at which water will be found, for a sufficient supply can be obtained only from the subterranean passages which are separated by dense rock. Such a passage may be encountered at 20 feet or 100 feet or the drill may encounter none at all. Furthermore such water is peculiarly liable to contamination. Surface impurities enter the limestone sinks which deliver the water to the passages. Passing through the rock in this way the water is not purified as it is by slow percolation. For similar reasons the water is muddy after each rain for the loess readily washes into the sinks.

Cisterns.—On account of these disadvantages the custom of making cisterns has gradually grown up in the regions of limestone sinks and this custom has spread to some extent beyond their borders. The custom has been of such slow growth and long standing that many of the people can assign no reason for their use of cisterns rather than wells. Still there are individual instances in recent years where the decision was consciously made, following a conspicuous prevalence of some disease; or at other times because of a failure to find water in the limestone after drilling deep at great expense.

1 The readiness of percolation as well as the complacency with which the dangers of contamination are regarded by a large part of the population are well illustrated by an incident which occurred in the work of the St. Louis Health Department several years ago. A bottle of water was brought to that department by a man who had made a somewhat sudden discovery that his own well, from which it was taken, was yielding "mineral water." This promised to be a source of income and he desired the opinion of the Health Department as to the value of the water in a commercial way. On inquiry it appeared that the peculiar taste (supposedly indicating iron) had first appeared about a week before the sample was brought. Further inquiry brought out the following facts: The well was situated about one block from an abandoned quarry, one of the deep pits of which had been used as a dumping ground for refuse. The odor of this refuse at last attracted public attention and the Health Department ordered that sulphate of iron be used to disinfect it. Four days later this iron appeared in the well at least a block away, showing that the intervening limestone was little more than a sieve. The iron compound was detected in traveling the path which the filth had traveled undetected for years. It is needless to say that the water was not put on the market. On the contrary, the well was condemned and ordered filled up against the owner's protest. Thousands of wells have been thus condemned within the past 20 years. The number of such wells in use 20 years ago was about 8,000. Present laws in Missouri do not admit the closing of all shallow wells by general order. It is necessary to produce sufficient evidence against each particular well.

Springs.—Some springs are found, the most noteworthy of which is Falling Spring about 2 miles south of Stolle, Illinois. At this place is an almost vertical cliff of the St. Louis limestone nearly 150 feet high. Half way up this cliff is the opening of a subterranean passage from which water issues in sufficient quantity to fill a 12 or 15 inch pipe. This passage is essentially a cave, and the water enters it through some of the sinks which abound on the adjacent upland. Smaller springs are found at many places where the loess rests directly on less pervious rock, especially the shales of the Coal Measures. Where the latter with a downward slopping surface crops out on a hillside, surface waters percolate downward to the base of the loess and then follow the sloping surface of the impervious bed until they issue as springs or as unconcentrated seepage.

Deep Wells.—Water under artesian pressure (though not necessarily rising to the surface) is found in various formations. Many deep wells derive their supply from the St. Louis limestone. This water is generally pleasant to the taste though it is occasionally salt and always hard. Deep wells in this formation are for the most part confined to the cities where their waters are used by various manufacturing concerns. The Carboniferous sandstones also yield water, especially the Chester which is the source of the city water supply at Belleville where it is reached by some dozens of wells from 500 to 600 feet deep. Farther north the water from this same stratum is too salt for use. Some lower formations of the Carboniferous also yield water. The Osage limestone, for example, was recorded as a "salt sand" by the drillers of the Keller oil well three miles south of Peters Station, Illinois. The same saltiness is noted in most wells deriving their water from the lower horizons of the Carboniferous.

Of all buried strata, probably the most abundant water bearer is the St. Peters sandstone. Within this area it is reached by wells ranging in depth from 1,000 to 2,000 feet. Among these is the well-known Belcher well of St. Louis, about one-half mile north of the Eads bridge. This well, which pierces the St. Peters sandstone at a depth of between 1,500 and 1,640 feet yields about 40 gallons per minute of water which is strongly charged with various salts. The most abundant of these is common salt. All wells in this sandstone yield similar water, though not always so strongly mineralized.

Flowing wells in this area are not confined to any one horizon. A small flowing well at Keyes' dairy farm, 2 miles east of Valley Park, Missouri, is only 300 feet deep and seems to derive its water from the Osage limestone which there comes to the surface. At Edgemont, Illinois, a flowing well 782 feet deep taps the same formation. Another, 1,506 feet deep at Peters' Station, Illinois, seems to produce from the Trenton. Most flowing wells however obtain their supply from the great reservoir of water in the St. Peters sandstone. The Belcher well in St. Louis flows, likewise a similar one at Granite City, Illinois. A well near Monks Mound, drilled for oil, yields salt water, chiefly from the St. Peters at a depth of about 2,000 feet. A flowing well at Mascoutah, Illinois, yields water from the same formation, which is there more than 3,000 feet deep. In none of these wells is the pressure sufficient to cause a very large flow.

Transportation Facilities.

RIVERS.

The commanding position which St. Louis occupies with respect to river transportation is evident. It is essentially at the junction of the Mississippi and the Missouri and profits by trade brought by the Ohio, Tennessee, Cumberland, Wabash and Illinois rivers. River transportation was a common and highly important phase of business in the first half of the nineteenth century. Towns and cities were built along the great rivers with special reference to good wharfage for the river trade. The influence of the river trade on the growth of St. Louis is suggested by the fact that in 1845 there 2,050 steamboat arrivals at the city. The first steamboat to visit St. Louis was the General Pike, in 1817. Prior to this it had cost 50 cents a pound to pole or row freight from New Orleans to St. Louis; twenty years later the freight rate for the same trip was 2 cents a pound.

The great development of railroad systems in the second half of the century caused the river trade to fall to a small fraction of its former volume. The Missouri river was abandoned entirely as a trade route and many of the towns on its banks which had flourished by its trade dropped out of notice and some of them almost out of existence. Those which had in the meantime been reached by railroads were in a condition to survive and begin life anew but the presence of the river added little or nothing to their opportunities.

The revival of river transportation, long prophesied, may now almost be said to have begun, and the natural advantage of a location near the junction of great routes like the Mississippi and Missouri may be looked upon as more important for the future than in any time past. The relation of these water routes to the several industries of which St. Louis is a great center may best be pointed out in considering those industries.

RAILROADS.

St. Louis is also an important railroad center, but this must be regarded quite as much as an effect as a cause of its importance. The number of places at which the Mississippi can be conveniently bridged is indeed limited, but they are not so few as to cause a great city to grow up at each such crossing.

Geographical Relations of Industries.

FOUNDING OF ST. LOUIS.

The site of St. Louis was chosen by Pierre Ligueste Laclede in 1764. He had been a resident of Louisiana, at which place as head of the Louisiana Fur Company, he was given exclusive rights in the fur trade with the Indians on the Missouri. He had suffered much from floods in Louisiana and, determining to have a home not only nearer the seat of his trade but beyond the reach of floods, he sailed up the river in 1763, going beyond the mouth of the Missouri. The site of St. Louis was marked on the way up and confirmed on returning.

The dominant considerations in the selection of the site of St. Louis were as follows: (1) It was desirable that the new post should be *at or below* the mouth of the Missouri river, since it must be reached by boats descending both streams, and the ascent of either by loaded boats was difficult. (2) The ground at this point was high enough to be beyond the reach of floods but not so high as to make loading and unloading of cargoes difficult. It is the first high ground south of the mouth of the Missouri not separated from the river by a flood plain. (3) The channel of the Mississippi below St. Louis has a minimum depth of 6 feet while above the city its minimum depth is only 3 to 5 feet. The effect of this was to bring together two fleets of boats, one adapted to the deeper water below the city and the other to the shallower water above, and to make of St. Louis a reloading point where cargoes were discharged from one fleet to the other. (4) It was necessary that the site to be chosen by Laclede should be on the west side of the Mississippi, since the land on the east side of that river had been ceded to England in the previous year, 1763.

The influence of high ground and freedom from floods in determining the prosperity of the city is made clear by contrasting the growth of St. Louis with that of Cahokia, Ill., which was founded earlier but located on the flood plain across the river, and which is therefore subject to annual floods. In other respects Cahokia was as well situated as St. Louis, but it is now a small village without a town organization or even a post office.

The original topography of this site was strongly marked by limestone sinks. Large areas now covered by the city and graded to an approximate level were as closely pitted with such sinks as certain areas in the southern part of the city or near Jefferson Barracks or south of the Prairie du Pont Creek are at present. Near 18th street, north of where the Union Station now stands, was a fine spring. Another lay south of it on the opposite side of the valley now occupied by the railroad yards. These were important considerations at that time. A small stream, later known as Mill Creek, flowed eastward toward the Mississippi, along a line roughly marked by the present railroad yards. The creek has entirely disappeared and its place is now taken by a main line of sewers. A dam was built across the small stream near the present 9th street, and this supplied power for the young community.

VARIOUS INDUSTRIES.

As may be inferred from the circumstances of its founding, the fur trade was the most important industry of the city during its youth. The position which this occupied may be inferred from the fact that deer hides (or certificates for them) were standard currency until about the time of the Louisiana Purchase. Within a few years after the establishment of the post, St. Louis fur traders are said to have employed annually, in traffic with the Indians, eight thousand pounds worth of European goods, on which some two hundred per cent profit was derived.[1] As late as 1843 there were 150 fur-trading posts in the western country tributary to St. Louis.[2]

The source of furs for the St. Louis trade has long since ceased to be the Mississippi basin and is now Canada and Alaska, but such is the effect of an original impetus that St. Louis remains to this day the world's chief market for raw furs, that is, it leads as a primary market, where furs are brought directly from the trappers. In the sale of finished goods it is far outstripped both by London and New York. The absolute volume of the annual trade ($9,000,000 in 1905) is far greater than in the youth of the community, but it is now outranked by a score of other industries.

It is easily apparent that no event of history and no possible human effort could have concentrated this industry at a point not naturally favored. Many fur trading stations were established, but the ultimate preeminence came naturally to the one most favorably situated with respect to the lines of traffic then in use. Those were, of course, the great rivers. The countless tributaries of the upper Mississippi and Missouri ramify into every quarter of the great area where fur trading was most important. Whether followed by canoes in summer or by sledge or on foot in winter they were at all times the natural routes of travel and all led to the common point near the junction of the Missouri and Mississippi.

The relations of certain industries to this great center of trade and population are so simple that it is sufficient to call attention to them without explanation. Thus most of the raw material of the $5,000,000 worth of clay products sold in 1905 was obtained within the city limits of St. Louis.

The business of meat packing (more than $17,000,000 in 1905), the purchase of hides ($19,000,000 in 1905) and the manufacture of boots and shoes ($50,000,000 in 1905) form a group whose relations to one another are evident. Equally evident is their relation to the great agricultural district surrounding the city and the grazing lands of the West and Southwest.

A similar group of industries is based on lumber. This is one of the chief articles of commerce which can profitable be shipped by water, and the chief lumber producing regions of America within the past 50 years lie upstream from St. Louis. The city's trade in lumber in 1905 amounted to more than $45,000,000. Since it is said to be the largest hardwood lumber market in America, it is not surprising that the trade in furniture and kindred lines amounted in the same year to $63,000,000. The city manufactures more street and railway cars than any other ($25,000,000 worth in 1905), and it claims the largest house for woodenware, a line in which the same year's trade was $15,000,000.

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1 Pittman. European Settlements on the Mississippi (1770), pp. 30-31.
2 Chittenden. History of the American Fur Trade of the Far West, Vol. I, p. 44.

The reason why St. Louis should be the largest manufacturer of tobacco in the world is less obvious. The nearest tobacco raising district of first rank is in western Kentucky, about 150 miles away, though connected by water routes. The reasons for this (not very large) discrepancy between the center of production and the center of trade is to be sought in commercial rather than physiographic conditions. The value of tobacco manufactured in 1905 was about $30,000,000.

The importance of St. Louis as a center of business in general hardware is likewise to be explained more by the history of commerce than by physiographic influence. The city claims the largest wholesale hardware house in the country, and the business in this line amounted in 1905 to $35,000,000.

That not all commercial development is determined by physiographic influence is well illustrated in the drug and chemical trade of St. Louis which reached $23,000,000 in 1905. The reasons for the prominence of this business is commonly ascribed to a large immigration of educated Germans following the political troubles of 1848 in Germany. The brewing of beer to the value of $22,000,000 in a single year is to be recorded rather as a phase of this same group of industries than as an indication of a great beer drinking population or easy access to raw materials. The proportion of foreign born to native population is notably smaller in this section of the United States than around the Great Lakes or in Southern New England. Barley for malt must be brought at least several hundred miles from northern Iowa and Wisconsin.

St. Louis is the money center for a group of states lying chiefly to the west and south. The enormous amounts required annually to move the crops of this great region is supplied in large part from this center. The bank clearings in 1905 amount to nearly $3,000,000,000.

AGRICULTURE ON THE AMERICAN BOTTOMS.

The term "American Bottoms" is variously used, being sometimes made to apply to all that part of the Mississippi flood plain in Illinois between the mouth of the Missouri and that of the Ohio. More frequent usage limits the name to that exceptionally broad part of the flood plain which extends from Alton on the north to Prairie du Pont Creek on the south, a distance of some 23 miles within which the width of the flood plain on the Illinois side averages about 7 miles. The soils of this area have already been mentioned (See p. 64). The possibilities of agriculture on its broad and level surface have attracted attention from the earliest settlement. The two great problems are drainage and the prevention of floods. Various schemes have been devised and small areas have indeed been protected from overflow, but the great area of potential farming land remains to be reclaimed by a more comprehensive plan than has yet been attempted. The problem has been carefully studied[1] and with the increasing demand for farming land in the United States, the greater part of this area will doubtless at some time be reclaimed.

The dikes which at present protect East St. Louis and other parts of the American Bottoms in a more or less imperfect way are in the main

[1] See Helm, Edwin C. The Levee and Drainage Problem of the American Bottoms. Journal of the Association of Engineering Societies, Vol. XXXV, pp. 91-116, 1905.

used as railroad embankments. More than half of them were built for this purpose, protection of land from floods being only a secondary consideration. The Baltimore & Ohio embankment has thus become the main protection of East St. Louis on the north side, as the Illinois Central is on the south. The Chicago & Alton embankment affords protection to a large area in Madison county.

Soon after the Civil War an extensive reclamation project was formed which resulted in the building of a levee from East St. Louis, southwestward to a point opposite Carondelet, Mo. The reclamation scheme was never completed and the levee mentioned passed into the hands of a railroad company who built the so-called Conoloque (East St. Louis and Carondelet) railroad, now a part of the St. Louis Terminal System. It affords some protection from floods even at present and its course is so well chosen that it will doubtless in the future become part of a much more perfect levee system.

Similarly, a tract of nearly 30 square miles lying north of East St. Louis and west of Horseshoe and Long Lakes, is partially protected by the so-called American Bottom levees, which were built some time in the 80's for this express purpose. The one on the south side of the tract has since been occupied in a part of its course by the St. Louis, Troy & Eastern Railroad. The levee on the west, near the river, is not used by any railroad. Various other levees built by other corporations and individuals are useful though few withstand great floods. The plans have not been comprehensive, but have looked to the protection of limited areas. The future will doubtless see the reclaimable area protected as a whole, so subdivided by embankments that the damage from a broken dike at any point will be localized.

LIST OF PUBLICATIONS.

A portion of each edition of the Bulletins of the State Geological Survey is set aside for gratuitous distribution. To meet the wants of libraries and individuals not reached in this first distribution, 500 copies are in each case reserved for sale at cost, including postage. The reports may be obtained upon application to the State Geological Survey, Urbana, Illinois, and cheeks and money orders should be made payable to F. W. DeWolf, Urbana.

LIST OF PUBLICATIONS.

BULLETINS.

Bulletin 1. The Geological Map of Illinois, by Stuart Weller. Including a folded, colored geological map of the State on the scale of 12 miles to the inch, with descriptive text of 26 pages. (Out of print.)

Bulletin 2. The Petroleum Industry of Southeastern Illinois, by W. S. Blatchely. Preliminary report descriptive of condition up to May 10th, 1906. 109 pages. (Out of print.)

Bulletin 3. Composition and Character of Illinois Coals, by S. W. Parr; with chapters on the *Distribution of the Coal Beds of the State,* by A Bement, and *Tests of Illinois Coals under Steam Boilers,* by L. P. Breckenridge. A preliminary report of 86 pages. Gratuitous edition exhausted. Sale price *25 cents.*

Bulletin 4. Year book of 1906, by H. Foster Bain, director and others. Includes papers on the topographic survey, on Illinois fire clays, on limestones for fertilizers, on silica deposits, on coal, and on regions near East St. Louis, Springfield and in Southern Calhoun county. 260 pages. Gratuitous edition exhausted. Sale price *35 cents.*

Bulletin 5. Water Resources of the East St. Louis District, by Isaiah Bowman, assisted by Chester Albert Reeds. Includes a discussion of the topographic, geologic and economic conditions controlling the supply of water for municipal and industrial purposes, with map and numerous well records and analyses. Postage *6 cents.*

Bulletin 6. The Geological Map of Illinois, by Stuart Weller. Second edition. Includes a folded colored geological map of the State on the scale of 12 miles to the inch, with descriptive text of 32 pages. It includes corrections and additions to the former map and text and shows locations of mines where coal, lead, zinc and flourspar are produced. The great oil fields of southeastern Illinois are also outlined. Gratuitous edition exhausted. Sale price *45 cents.*

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Bulletin 9. Paving Brick and Paving Brick Clays of Illinois: Geology of Clays, Geological Distribution of Paving Brick Materials in Illinois, and Clays Tested Which are Suitable for Use in the Manufacture of Paving Brick, by C. W. Rolfe; Qualities of Clays Suitable for Making Paving Brick, Physical and Chemical Properties of Paving Brick Clays, and Pyro-Physical and Chemical Properties of Paving Brick Clays, by Ross C. Purdy; Qualities of High Grade Paving Brick and Tests Used in Determining Them, by A. N. Talbot; Construction and Care of Brick Pavements, by Ira O. Baker. 315 pages, 3 plates, and 33 figures. Postage *13 cents.*

Bulletin 10. The Mineral Content of Illinois Waters: Geological Classification of the Waters of Illinois, by J. A. Udden; *Classification of Waters According to Physical and Chemical Properties,* by Edward Bartow; *Methods and Interpretations of Analysis,* by Edward Bartow; *Boiler Waters,* by S. W. Parr; *Medicinal Springs,* by G. T. Palmer; *Water Analyses,* by Edward Bartow. 192 pages, 9 plates, 1 figure. Postage *7 cents.*

Bulletin 11. The Physical Feature of the Des Plaines Valley: Geography and History of the Des Plaines Valley. Structure of Bed Rock. Deposition of Paleozoic Sediments. Glacial and Inter-Glacial Deposits. Physiographic History of the Lower Des Plaines River. Physiographic History of the Upper Des Plaines River. Floods on the Des Plaines River. 103 pages, 9 plates, 21 figures. Postage *6 cents.*

Bulletin 12. Physiography of the St. Louis Area, by N. M. Fenneman.

Separates.

From Bulletin 8.

8a. Administrative Report for 1907, (with Abstracts of reports issued in 1907), by H. Foster Bain. 41 pages, 1 plate. Postage *2 cents.*

8b. Advance Abstracts from Educational Bulletins: Drainage about Springfield, by J. Claude Jones; *Bed Rock near Wheaton,* by Arthur C. Trowbridge; *Middle Portion of the Illinois Valley,* by Harlan H. Barrows. 12 pages, 1 plate, 4 figures. Postage *2 cents.*

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INDEX.

Index—Continued.

Index—Continued.

I.

Index—Continued.

Index—Concluded.